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URBAN TEMPERATURE EXCESS AS A FUNCTION OF URBAN PARAMETERS IN SZEGED, PART 1: SEASONAL PATTERNS

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Összefoglalás - A tanulmány a beépített városi felszín és a felszínközeli légtér hőmérsékleti eloszlása közötti kapcsolatot elemzi egy közepes méretű város, Szeged esetében. A város sík, alföldi területen fekszik és lakosainak száma 160 ezer. Az adatgyűjtés különböző időjárási helyzetekben, mobil mérésekkel történt 1999. március és 2000. február között. A vizsgálat célja az átlagos maximális városi hősziget területi szerkezetének megállapítása kriging eljárással megszerkesztett izovonalak segítségével az egy éves periódusban, valamint az ezen belül megkülönböztetett fűtési és nem fűtési időszakokban. Az eredmények szerint a városi hőmérsékleti többlet izotermái meglehetősen szabályos, méghozzá a külterülettől a belváros felé növekedő koncentrikus alakot vesznek fel, de a hősziget erősségében megfigyelhető egy évszakos változás. A legnagyobb érték az egész időszakban több mint 2,6°C, a nem fűtési periódusban több mint 3,1°C és a fűtési periódusban pedig több mint 2,1°C. A szabályosságtól való eltérések szoros kapcsolatban vannak a beépítettség mértékével.

Summary - This study examines the influence of urban factors on the surface air temperature field of the medium-sized city of Szeged, Hungary, using of mobile measurements under different weather conditions between March 1999 and February 2000. This city with a population of about 160,000 is situated on a low, flat flood plain. The efforts have been concentrated on investigating the maximum development of the urban heat island (UHI). Tasks include the determination of spatial distribution of mean maximum UHI intensity, using of standard kriging procedure in the one-year study period, as well as in the heating and non-heating seasons. The results indicate isotherms increasing in regular concentric shapes from the suburbs toward the inner urban areas with a seasonal variation in the UHI magnitude. In the city centre, the mean maximum UHI intensity reaches more than 2.6°C, 3.1°C and 2.1°C, respectively. As the patterns show, strong relationship exists between urban thermal excess and built-up density.

Key words: maximum urban heat island, mobil measurements, spatial distribution, grid network, built-up density, heating and non-heating seasons

INTRODUCTION

The temperature-increasing effect of cities caused by urbanisation (the so-called urban heat island - UHI) is one of the most deeply examined field of climatology. Features of the UHI are well documented from different cities mainly from the temperate zone (*e.g. Oke*, 1997; *Kuttler*, 1998) and one of the most difficult aspect of this phenomenon is studying of its peak development during the diurnal cycle.

Counting all weather conditions except rain, the main purpose of this study is to investigate the effects and interactions inside the city on the surface air temperature, a few hours after sunset when the UHI effect is most pronounced. To achieve this aim, we construct horizontal isotherm maps to show the average spatial distribution of maximum UHI intensity in the investigated period, as a whole and in the distinguished so-called heating and non-heating seasons. Then, we intend to reveal some obvious relationships between temperature patterns and urban factors using built-up (artifically covered surface) ratio within the city.

Further results - connected to the statistical elaboration of the same data set used in this study - can be found in the second part of our investigation (*Unger et al.*, 2001).

STUDY AREA AND METHODS

Szeged is located in the south-eastern part of Hungary on the Great Hungarian Plain (46°N, 20°E) at 79 m above sea level. The terrain of the city and its countryside is a large flat flood plain. The Tisza River passes through the city, otherwise, there are no large water bodies nearby. This geographical situation (no orographic climate influences) makes Szeged a good case for the study of a relatively undisturbed urban climate. Using Köppen's classification the area belongs to the climatic region *Cf*, which means a temperate warm climate with a rather uniform annual distribution of precipitation (*Table 1*). The regional climate of Szeged has, however, a certain Mediterranean influence. It appears mainly in the annual variation of precipitation, namely in every 10 years approximately 3 years show some Mediterranean (relatively high autumn-winter rainfall) characteristics (*Unger*, 1999).

The city's population of 160,000 (1998) lives within an administration district of 281 km^2 (*Firbás*, 1999). As for the city structure, its basis is a boulevard-avenue road system. Number of different land-use types are present including a densely built centre with medium wide streets and large housing estates of tall concrete blocks of flats set in wide green spaces. Szeged also contains areas used for industry and warehousing, zones occupied by detached houses, and considerable open spaces along the banks of the river, in parks and around the city's outskirts (*Fig. 1*).

Table 1 Monthly and annual means or sums of meteorological parameters in the region of Szeged (1961-1990)

Parameter	***J***	***F***	***M***	***A***	***M***	***J***	***J***	***A***	***S***	***O***	***N***	***D***	***Year***
Temperature (°C)	-1.8	1.0	5.6	11.1	16.2	19.2	20.8	20.2	16.4	11.0	5.1	0.6	10.4
Precipitation (mm)	29	25	29	40	51	72	50	60	34	26	41	40	497
Sunshine duration (h)	62	87	143	181	235	252	288	267	211	170	82	51	2029
Cloudiness (%)	70	68	63	60	58	54	45	42	45	49	69	76	58
Wind speed (ms^{-1})	3.3	3.4	4.0	3.7	3.2	2.9	2.9	2.7	2.6	3.0	3.0	3.7	3.2
Relative humidity (%)	85	82	73	68	66	67	65	67	70	73	83	87	74
Vapour pressure (hPa)	4.9	6.5	6.8	8.9	12.3	15	16	15.8	13.2	9.8	7.6	5.8	10.1

As the urban and suburban areas occupy only about 25-30 km^2, our investigation focused only on the inner part of the administration district (*Fig. 1*). This study area was divided into two sectors and subdivided further into 0.5 km x 0.5 km square grid cells (*Fig. 2*). The same grid size was employed, for example, in a human bioclimatological analysis of Freiburg, Germany, a city of similar size to Szeged (*Jendritzky and Nübler*, 1981) and in an other investigation of UHI in Seoul, Korea (*Park*, 1986). *Sailor* (1998) chose a 2 km x 2 km network for his hypothetical city, where he simulated the impacts of vegetative augmentation on the annual heating and cooling degree days.

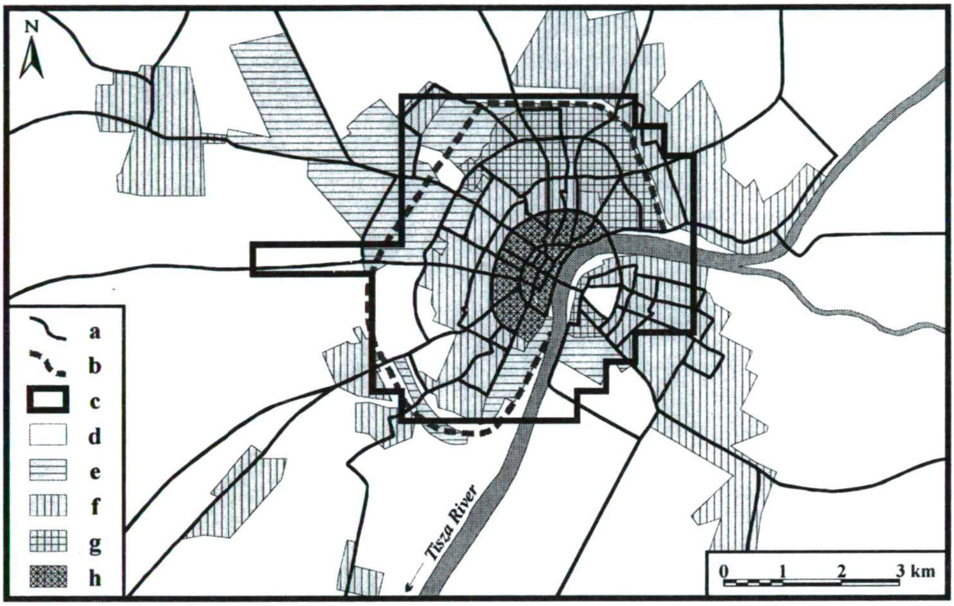

Fig. 1 Characteristic land-use types and road network in Szeged: (a) road, (b) circle dike, (c) border of the study area, (d) agricultural and open land, (e) industrial area, (f) 1-2 storey detached houses, (g) 5-11 storey apartment buildings and (h) historical city core with 3-5 storey buildings

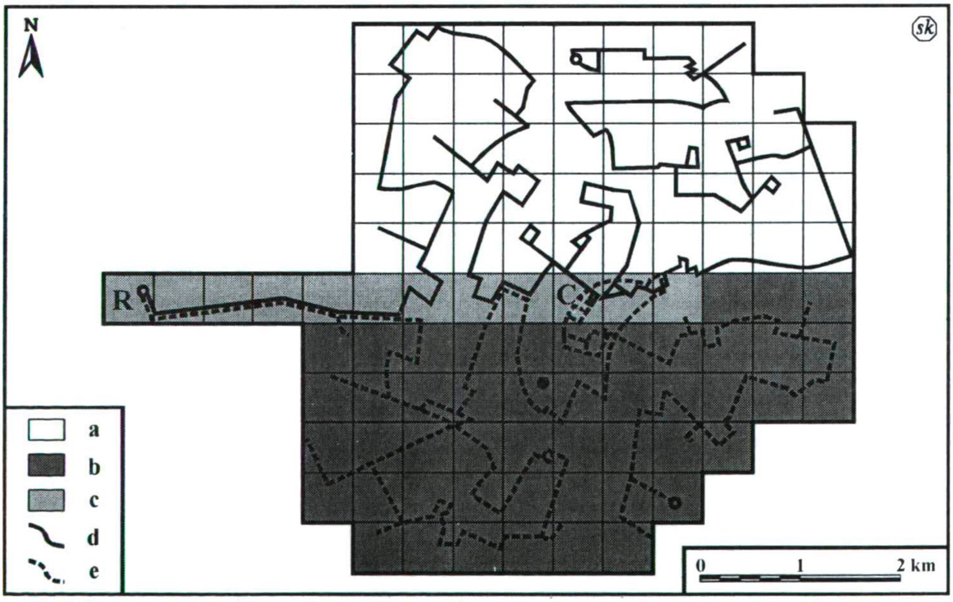

Fig. 2 Division of the study area into 0.5 km x 0.5 km grid cells: (a) northern sector, (b) southern sector, (c) overlap area and (d, e) measurement routes. The rural and central grid cell are indicated by R C, respectively and the permanent measurement site at the University of Szeged is indicated as •.

Therefore, our grid network can be regarded as a rather dense one. In the study area there are 107 grid cells totalling 26.75 km^2, covering the urban and suburban parts of Szeged (mainly inside of the circle dike that protects the city from floods caused by the Tisza River). The outlying parts of the city, characterised by village and rural features, are not included in the grid except for four cells at the western side of the area. These four cells are needed in order to determine the temperature contrast between urban and rural areas. The grid was established by quartering the 1 km x 1 km square network of the Unified National Mapping System (EOTR) that can be found on topographical maps of Hungary at the scale of 1:10,000.

The examination of the spatial and temporal distribution of surface air was based on mobile observations during the period of March 1999 - February 2000. In case of surface UHI and near surface air UHI investigations, the moving observation with different vehicles (car, tram, helicopter, airplane, satellite) is an often used process (e.g. *Johnson*, 1985; *Yamashita*, 1996; *Voogt and Oke*, 1997; *Klysik and Fortuniak*, 1999; *Tumanov et al.*, 1999).

In order to collect data on maximum UHI intensity (namely the temperature difference between urban and rural areas) at every grid cell, mobile measurements were performed on fixed return routes once a week during the studied period (altogether 48 times) to accomplish an analysis of air temperature over the entire area. This one-week frequency of car traverses secured sufficient information on different weather conditions, except for rain. *Table 2* contains the details of the one-year measurement campaign.

The division of the study area into two sectors was needed because of the large number of grid cells. The northern and southern sectors consisted of 59 grid cells (14.75 km^2) and 60 grid cells (15 km^2) respectively, with an overlap of 12 grid cells (3 km^2). The lengths of the fixed return routes were 75 and 68 km in the northern and southern sectors, respectively and took about 3 hours to traverse (*Fig. 2* and *Table 2*). Such long and return routes were necessary to gather temperature values in every grid cell and to make time-based corrections. Temperature readings were obtained using a radiation-shielded LogIT HiTemp resistance temperature sensor (resolution of 0.01°C), which was connected to a portable LogIT SL data logger (DCP Microdevelopments and SCC Research) for digital sampling inside the car. Since the data were collected every 16 s, at an average car speed of 20-30 km h^{-1} the average distance between measuring points was 89-133 m. The temperature sensor was mounted 0.60 m in front of the car at 1.45 m above ground to avoid engine and exhaust heat. This is similar to the measurement system used by *Ripley et al.* (1996) in Saskatoon, Saskatchewan. The car speed was sufficient to secure adequate ventilation for the sensor to measure the momentary ambient air temperature (*Fig. 3*).

After averaging the measurement values by grid cells, time adjustments to the reference time were applied assuming linear air temperature change with time. This linear change was monitored using the continuous records of the permanent automatic weather station at the University of Szeged (*Fig. 2*). The linear adjustment appears to be correct for data collected a few hours after sunset in urban areas. However, because of the different time variations of cooling rates, it is only approximately correct for suburban and rural areas (*Oke and Maxwell*, 1975). The reference time, namely the likely time of the occurrence of the strongest UHI, was 4 hours after sunset (in CET - Central European Time, see *Table 2*), a value based on earlier measurements in 1998 and 1999 (*Boruzs and Nagy*, 1999). Consequently, every grid cell of 59 in the northern sector or every grid cell of 60 in the southern sector can be characterised by one temperature value for every measuring night. These temperature values refer to the centre of each cell.

Table 2 Survey of mobile measurements in the study area of Szeged (March 1999 - February 2000)

Sector	No.	Date	Measuring period	Reference time (CET)	Number of measuring points
northern	1	02.03.1999	2h 56m	2130	663
	2*	09.03.1999	-	2130	-
	3*	31.03.1999	-	2200	-
	4	15.04.1999	3h 09m	2230	708
	5	29/30.04.1999	3h 04m	2245	686
	6	13/14.05.1999	3h 05m	2300	692
	7	25/26.05.1999	3h 15m	2315	731
	8	09/10.06.1999	3h 16m	2330	736
	9	23/24.06.1999	3h 07m	2330	699
	10	05/06.07.1999	3h 12m	2330	700
	11	21/22.07.1999	3h 19m	2330	763
	12	03/04.08.1999	3h 01m	2315	666
	13	17/18.08.1999	3h 04m	2245	682
	14	29.08.1999	2h 59m	2230	669
	15	14.09.1999	3h 07m	2200	699
	16	29.09.1999	3h 12m	2130	719
	17	12.10.1999	3h 14m	2100	725
	18	26.10.1999	3h 12m	2030	717
	19	12.11.1999	3h 10m	2015	711
	20	06.12.1999	3h 08m	2000	701
	21	07.12.1999	2h 59m	2000	668
	22	04.01.2000	3h 08m	2000	704
	23	14.01.2000	3h 04m	2015	689
	24	19.01.2000	3h 05m	2030	691
	25	01.02.2000	3h 05m	2045	693
	26	15.02.2000	3h 06m	2100	694
southern	1	16.03.1999	3h 03m	2145	683
	2	23.03.1999	3h 00m	2200	673
	3	06.04.1999	2h 52m	2215	643
	4	20.04.1999	2h 55m	2230	652
	5	10/11.05.1999	2h 47m	2300	624
	6	19/20.05.1999	2h 47m	2315	624
	7	01/02.06.1999	3h 09m	2330	707
	8	15/16.06.1999	3h 18m	2330	695
	9	29/30.06.1999	2h 59m	2330	661
	10	13/14.07.1999	2h 56m	2330	657
	11	31.07/01.08.1999	3h 00m	2315	674
	12	09/10.08.1999	3h 02m	2300	673
	13	24.08.1999	2h 51m	2230	628
	14	07.09.1999	2h 54m	2215	650
	15	20.09.1999	2h 50m	2145	636
	16	07.10.1999	2h 59m	2115	670
	17	18.10.1999	2h 58m	2045	666
	18	02.11.1999	3h 04m	2030	689
	19	18.11.1999	3h 05m	2000	698
	20	01.12.1999	2h 57m	2000	659
	21	18.12.1999	2h 50m	2000	636
	22*	11.01.2000	-	2015	-
	23	25.01.2000	2h 48m	2030	630
	24*	03.02.2000	-	2045	-
	25	08.02.2000	2h 54m	2100	649
	26	22.02.2000	3h 00m	2115	672

* no data available because of technical difficulties

Fig. 3 The measurement car with the temperature sensor (under the white cover)

We determined urban-rural air temperature differences (UHI intensity) by cells referring to the temperature value of the grid cell (the most western cell in the investigated area), where the synoptic weather station of the Hungarian Meteorological Service is located. This grid cell (labelled R) containing this station was regarded as rural (*Fig. 2*), because the records of this station were used as rural data in the earlier studies on the urban climate of Szeged (e.g. *Unger*, 1996, 1999). The 107 points (the above mentioned grid cell centerpoints) cover the urban parts of Szeged and they provide an appropriate basis to interpolate isolines. The isolines, therefore, can show detailed descriptions of thermal field within the city at the time of the strongest effects of urban factors. In order to draw the isotherms, a geostatistical gridding method, the standard kriging procedure was used.

The parameters of land-use for the grid cells were determined by GIS (Geographical Information System) methods combined with remote sensing analysis of SPOT XS images (*Mucsi*, 1996). Vector and raster-based GIS database were produced in the Applied Geoinformatics Laboratory of the University of Szeged. The digital satellite image was rectified to the EOTR using 1:10,000 scale maps. The nearest-neighbour method of resampling was employed, resulting in a root mean square value of less than 1 pixel. Because the geometric resolution of the image was 20 m x 20 m, small urban units could be assessed independently of their official (larger scale) land-use classification. Normalised Vegetation Index (*NDVI*) was calculated from the pixel values, according to the following equation:

$$NDVI = (IR-R)/(IR+R)$$

where *IR* is the pixel value in the infrared band and *R* is the pixel value in the red band. The range of *NDVI* values is from -1 to +1 indicating the effect of green space in the given spatial unit (*Lillesand and Kiefer*, 1987). Built-up, water, vegetated and other surfaces were distinguished according to the *NDVI* value. The spatial distribution of these land-use types of each grid element was calculated using cross-tabulation.

The ratio of the built-up area to the total area by grid cells in 25% increments is displayed in *Fig. 4*. This figure shows, that, for example, the location of the Tisza River (low built-up ratio) is clearly recognised with its east-to-south curve in the south-eastern part of the study area (see also *Fig. 1*).

SPATIAL DISTRIBUTION OF THE MAXIMUM UHI

In this part of the investigation not only the one-year period will be investigated, but within this period we distinguish the so called heating (between 16 October and 15 April) and non-heating (between 16 April and 15 October) seasons.

It can be seen in *Figs. 4, 5* and *6* that built-up density has a significant influence on the spatial patterns of the mean maximum UHI intensity (which is at 4 hours after sunset as supposed). The most obvious common features of these patterns are that the isotherms show almost regular concentric shapes with values increasing from the outskirts toward the inner urban areas. A vigorous deviation from this concentric shape occurs in the north-eastern part of the city, where the isotherms stretch toward the suburbs. This can be explained by the influence of the large housing estates with tall concrete buildings located mainly in the north-eastern part of the city with a built-up ratio higher than 75% (*Fig. 1*).

For the one-year period (*Fig. 4*), as it was expected, the highest differences (more than 2.5°C) are concentrated mainly in the densely built-up city centre (>75%) covered by about 2.5 grid cells (about 0.6 km^2). The strongest intensity (2.60°C) occurs in the central grid cell (C). A mean maximum UHI intensity of higher than 2°C indicates significant thermal modification. In this period in Szeged, the extension of the area, characterised by significant thermal modification, is about 19 grid cells (4.5-5.0 km^2), which is about 18% of the total investigated area.

In the non-heating season, the spreading out of the isolines of 2.25°C and 2.5°C to the north-west of the centre, and the isolines of 1.5°C and 1.75°C to the south-west are also caused by the high built-up ratio of more than 75% (*Fig. 5*). The highest differences (more than 2.75°C) are concentrated in the densely built-up city centre (>75%) covered by about 8 grid cells (2 km^2). The greatest intensity (3.18°C) is to the north of the central grid cell (C) in an adjacent cell. The mean maximum UHI intensity of higher than 2°C relatively large compared to the size of the study area. It covers about 40 grid cells (10 km^2), which is about 37% of the investigated area.

In the heating season, the high built-up ratio of more than 75% also caused the streching out of the isoline of 1.5°C to the north-west, and the isolines of 1°C and 1.25°C to the south-west (*Fig. 6*). The highest differences (more than 2°C) are concentrated in the city centre (>75%), covered by less than 2 grid cells (0.5 km^2), which is only about 2% of the total area. The strongest intensity (2.12°C) occurs in the central grid cell (C).

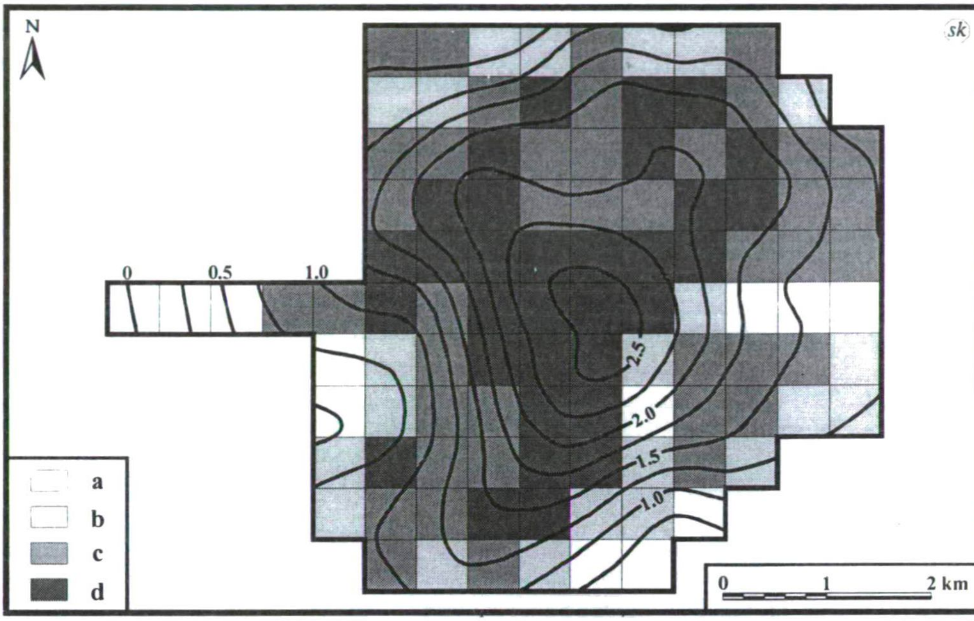

Fig. 4 Spatial distribution of the mean maximum UHI intensity (°C) and built-up density of the study area by grid cells (ratio of the built-up area to the total cell area: a/ 0-25%, b/ 25-50%, c/ 50-75% and d/ 75-100%) during the studied one-year period (March 1999 - February 2000) in Szeged

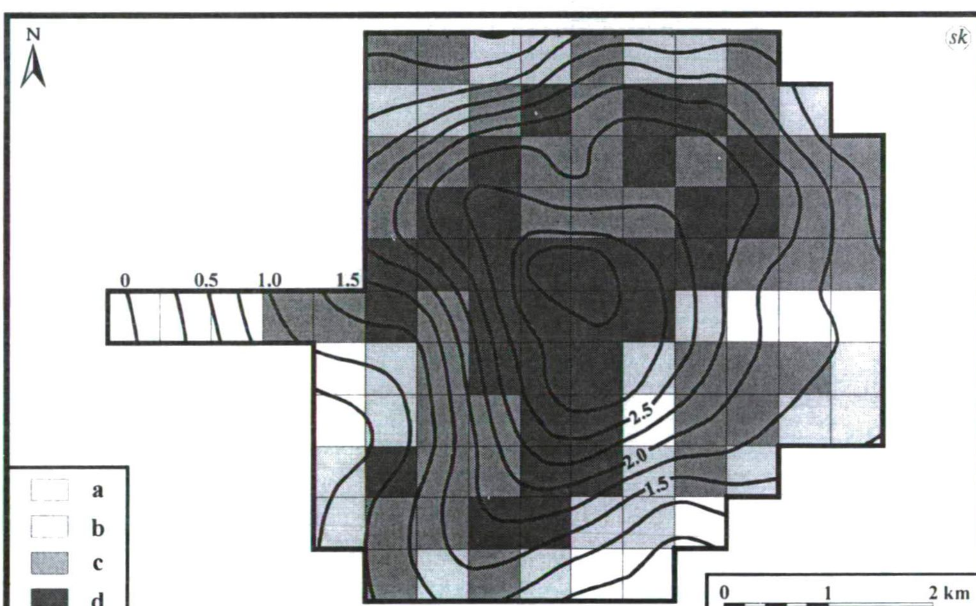

Fig. 5 Spatial distribution of the mean maximum UHI intensity (°C) during the non-heating season (16 April - 15 October) in Szeged

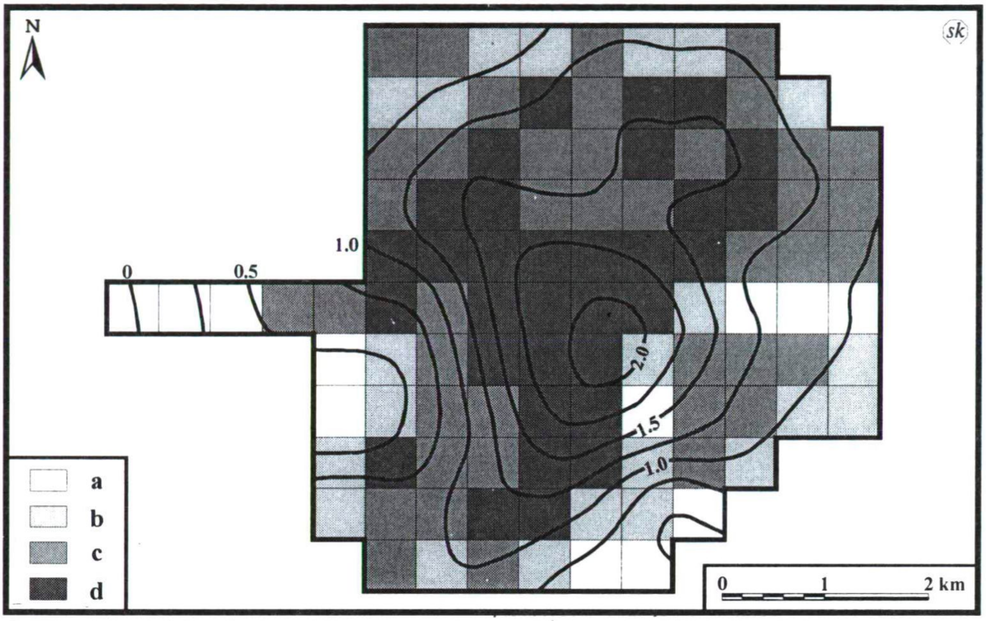

Fig. 6 Spatial distribution of the mean maximum UHI intensity (°C) during the heating season (16 October - 15 April) in Szeged

CONCLUSIONS

The seasonal spatial distribution of the maximum urban heat island and its relationship with built-up density is investigated in the present study. The results indicate that:

- The spatial patterns of the maximum UHI intensity have regular concentric shapes and the isotherms increase from the outskirts towards the central urban areas in all the three studied periods.
- The anomalies in the regularity are caused by the alterations in the built-up density.
- There are significant differences in the magnitudes of the seasonal (heating and non-heating) patterns. The area of the mean maximum UHI intensity of higher than 2°C - indicates significant thermal modification caused by urbanisation - is 18 times larger in the non-heating than in the heating season (2% and 37%, respectively).

The seasonal differences may be formed rather as a consequence of different weather characteristics in the two seasons than as a consequence of heating or non-heating of inhabitants. This explanation is supported by *Klysik and Fortuniak* (1999) who found similar differences in the UHI intensities between warm and cold seasons in Lódz, Poland. As in Poland, in Hungary (particularly in the Szeged region) the climate conditions in winter, conducive to the formation of UHI, are less common (*Table 1*). Thus, the role of appropriate weather conditions (stronger solar radiation income, more frequent clear sky and weak wind in the warmer, therefore non-heating season) is more pronounced in the development of UHI than the building heating in urban areas. Consequently, in case of Szeged, the significance of artifical heating in the development of UHI is rather limited.

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URBAN TEMPERATURE EXCESS AS A FUNCTION OF URBAN PARAMETERS IN SZEGED, PART 2: STATISTICAL MODEL EQUATIONS

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Összefoglalás - A tanulmány a városi felszín tényezőinek a hőmérsékleti mezőre való kvantitatív hatását elemzi egy közepes méretű város, Szeged esetében. Az adatgyűjtés különböző időjárási helyzetekben, mobil mérésekkel történt 1999. március és 2000. február között. A vizsgálat célja olyan statisztikus modellegyenletek felállítása, amelyek leírják ezeket a hatásokat az egy éves időszakban és az ezen belül megkülönböztetett fűtési és nem-fűtési periódusokban. A városi felszínparaméterek (beépítettség, vízfelület és a városközponttól való távolság egy négyzetes grid-hálózatban) hatását a városi hőszigetnek a napi meneten belüli legerőteljesebb kifejlődésére a többszörös korreláció- és regresszió-analízis alkalmazása tárja fel. Az eredmények szerint szoros kapcsolat létezik a városi hőmérsékleti többlet és a távolság, valamint a beépítettség mértéke között, viszont a vízfelületek szerepe ebben az esetben nem számottevő.

Summary - This study examines the quantitative influence of urban surface factors on the surface air temperature field of the medium-sized city of Szeged, Hungary, using of mobile measurements under different weather conditions between March 1999 and February 2000. Tasks include the determination of statistical model equations in the studied periods, distinguishing heating and non-heating seasons within the one-year period. Multiple correlation and regression analyses are used to examine the effects of urban surface parameters (land-use characteristics and distance from the city centre determined in a grid network) on the urban heat island (UHI) in its peak development during the diurnal cycle. The results indicate that strong relationships exist between urban thermal excess and distance, as well as built-up ratio, but the role of water surface is negligible in this case.

Key words: maximum urban heat island, built-up ratio, water surface ratio, distance, grid network, statistical analysis, regression equations

INTRODUCTION

The detection of real factors and physical processes generating the distinguished urban climate is extremely difficult because of the very complicated urban terrain (as regard surface geometry and materials) as well as artificial production of heat and air pollution. The simulation of these factors and processes demands complex and expensive instrumentation, and sophisticated numerical and physical models. Despite these difficulties, several models have been developed for studying small-scale climate variations within the city, including the ones based on energy balance (*Tapper et al,* 1981; *Johnson et al.*, 1991; *Myrup et al.*, 1993), radiation (*Voogt and Oke*, 1991), heat storage (*Grimmond et al.*, 1991), water balance (*Grimmond and Oke*, 1991) and advective (*Oke*, 1976) approaches.

The temperature alteration (urban heat island - UHI) caused by settlements is the most obvious and characteristic phenomenon of the urban climate. As an other solution of the above mentioned problems, utilisation of statistical models may provide useful tools, which give us quantitative information about the magnitude, as well as spatial and temporal features of the UHI intensity (defined as the temperature difference between urban and rural areas) by employing urban and meteorological parameters. Some examples of the modelled variables (surface and near surface air UHI intensity or even the possible maximum UHI intensity) and the employed variable parameters are gathered in *Table 1*.

Table 1 Survey of some statistical models with modelled UHI variables, employed parameters and authors

Modelled variable	***Employed parameters***	***Author(s)***
UHI intensity	wind speed, cloudiness	*Sundborg* (1950)
UHI intensity	population, wind speed	*Oke* (1973)
max. UHI intensity	population	
UHI intensity	wind speed, cloudiness, atmospheric stability, traffic flow, energy consumption, temperature	*Nkemdirim* (1978)
UHI intensity	wind speed, land-use type ratios	*Park* (1986)
max. UHI intensity	impermeable surface, population	
UHI intensity	cloudiness, wind speed, temperature, humidity mixing ratio	*Goldreich* (1992)
surface UHI intensity	solar radiation, wind speed, cloudiness	*Chow et al.* (1994)
UHI intensity	built-up area, height, wind speed, time, temperature amplitude	*Kuttler et al.* (1996)

The aim of this paper was to determine quantitative influences of the urban surface factors on the patterns of urban-rural temperature differences at the time of the strongest development during the diurnal cycle in the whole period, as well as in the so-called heating and non-heating seasons.

STUDY AREA AND METHODS

Features of the study area, method of the measurements, data base, grid network, determination of the land-use features and their ratios are described in details in the paper which contains the results of the first part of our investigation (*Unger et al.*, 2001).

In order to assess the extent of the relationships between the maximum UHI intensity and various urban surface factors, multiple correlation and regression analyses were used. The selection of the parameters was based on their role in determining small-scale climate variations (*Adebayo*, 1987; *Oke*, 1987; *Golany*, 1996).

The selected urban parameters were percentage of built-up area (artifically covered surface - building, street, pavement, parking lot, etc.) and water surface by grid cells, as well as distance to the city centre (grid cell labelled C, see *Fig. 1*). This distance can be considered as an indicator of the location of a cell within the city. These three parameters are constants but not variables for the complete (one-year long) measurement period. However, in each cell their values vary from place to place within the city. They are constants temporally but variables spatially. Searching for statistical relationships, we will take into account that our parameters are at once variables and constants.

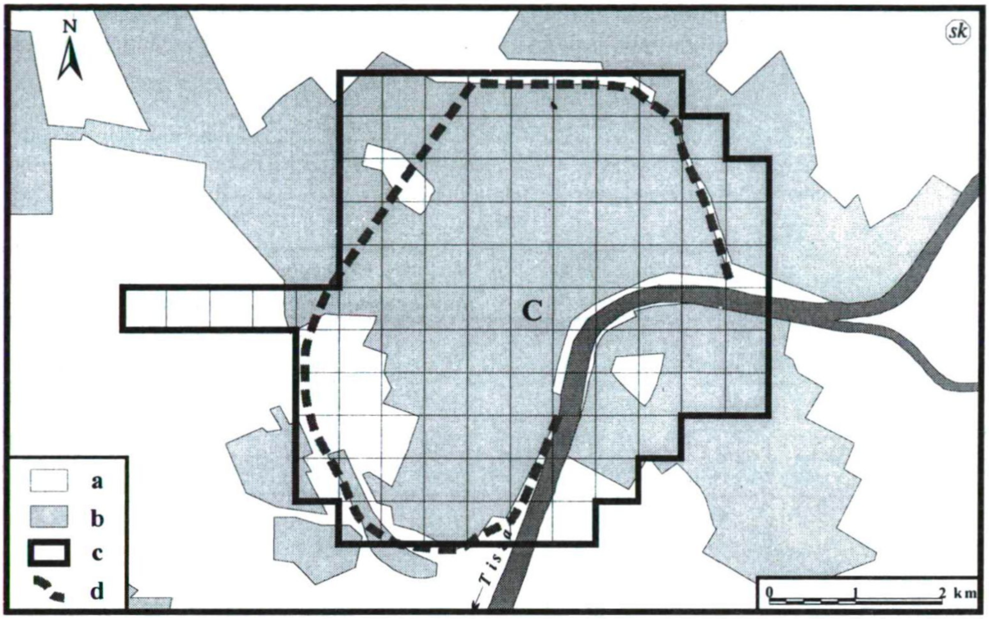


Fig. 1 Scheme of the urban area of Szeged and division of the study area into 0.5 km x 0.5 km grid cells (a: open land, b: urban area, c: border of the study area, d: circle dike). The central grid cell is indicated by C.

STATISTICAL RELATIONSHIPS

In this paper the one-year period, as well as the so-called heating (between 16 April and 15 October) and the non-heating (between 16 October and 15 April) seasons will be investigated.

In order to determine model equations for the maximum value of UHI intensity in the diurnal temperature course (ΔT) we use the earlier mentioned parameters (their labels are in brackets): distance from the central grid cell in km (D), ratio of built-up surface as a percentage (B) and ratio of water surface as a percentage (W). These parameters are variables spatially, namely by grid cells but constants temporally.

The bivariate analysis will be accurate if the total period averages of ΔT for each cell are correlated against each of the cell value of D, B and W, thus the time averages of the maximum UHI intensities vary by grid cells (the number of data pairs is $n = 107$).

Table 2 contains the results of the bivariate correlation analyses on ΔT against the urban surface parameters considered in this study. As the table shows, among the examined parameters D has the largest correlation coefficients ($r_{\Delta T,D}$). This fact support the establisment of *Unger et al.* (2001) on the regular concentric shapes of the UHI isotherms in szeged. The first two coefficients (D, B) are significant at 0.1% in all the three periods. The strong relationships between ΔT and D as well as B by periods can be seen also in the *Figs. 2, 3* and *4*. The ratio of water surface seems not to be important ($r_{\Delta T,W} < 0.06$ always, so it is not significant even at 10% level), for this reason it is not necessary to be used in the multiple regression equations. The explanation of this statistically insignificant role in the development of the maximum heat island in Szeged is that water surfaces can be found only in 39 grid cells from the total number of 107 and their ratio only a few percentage in most of the grids.

Table 2 Values of bivariate correlation coefficients between the average of maximum UHI intensity (ΔT) in °C and urban surface parameters (D - distance from the city centre in km, B - ratio of built-up area as a percentage and W - ratio of water surface as a percentage) by grid cells in different periods in Szeged (n = 107)

	March 1999 - February 2000		***16 April - 15 October (non-heating season)***		***16 October - 15 April (heating season)***	
Bivariate correlation coefficient (n = 107)	***Value***	***Significance level***	***Value***	***Significance level***	***Value***	***Significance level***
$r_{\Delta T,D}$	-0.837	0.1%	-0.861	0.1%	-0.760	0.1%
$r_{\Delta T,B}$	0.685	0.1%	0.675	0.1%	0.674	0.1%
$r_{\Delta T,W}$	0.044	-	0.056	-	0.020	-

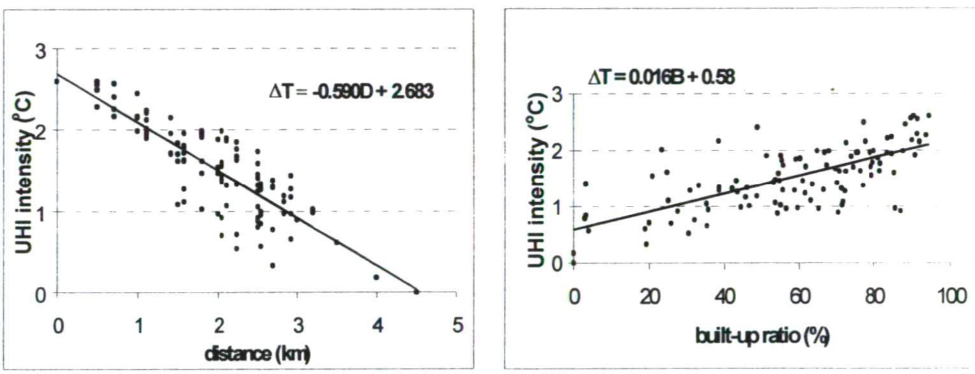


Fig. 2 Maximum UHI intensity (ΔT) as a function of the distance from the centre (D) and built-up ratio (B) with the best fit regression lines in the one-year period (March 1999 - February 2000) in Szeged

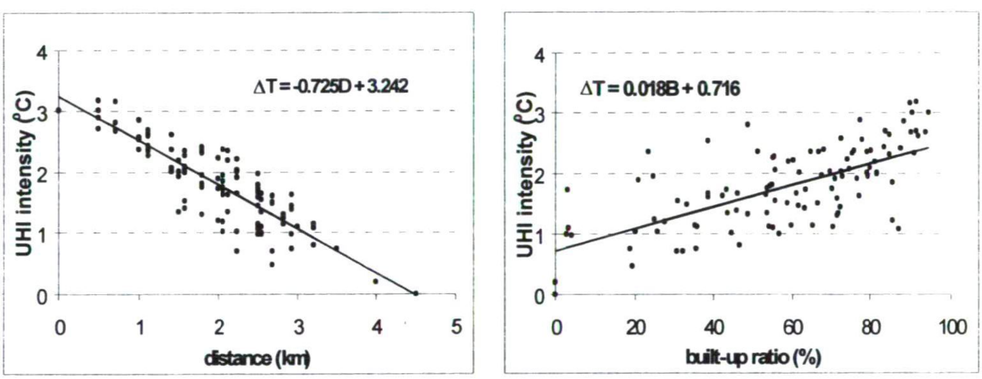
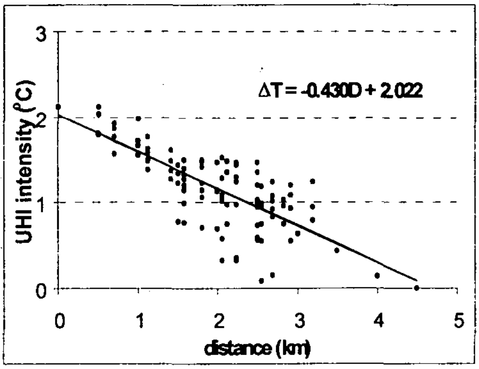


Fig. 3 Maximum UHI intensity (ΔT) as a function of the distance from the centre (D) and built-up ratio (B) with the best fit regression lines in the non-heating season (16 April - 15 October) in Szeged



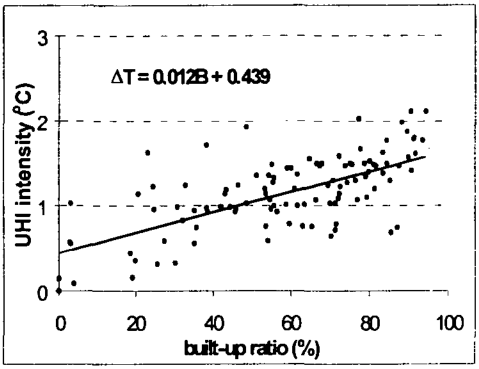


Fig. 4 Maximum UHI intensity (ΔT) as a function of the distance from the centre (D) and built-up ratio (B) with the best fit regression lines in the heating season (16 October - 15 April) in Szeged

The sequence of the parameters, entered in the multiple stepwise regression, was determined with the help of the magnitude of the bivariate correlation coefficients. *Table 3* contains the results of this stepwise regression on ΔT against the urban surface parameters in the three investigated periods. As the results show the distance from the city centre is most pronounced, but the role of the built-up density is also important. The improvements in the explanation caused by the entering of B, namely the differences as a percentage in the correlation coefficients in the fourth column of the table (Δr^2) of 6.8%, 5.3% and 8.9% cannot be neglected. The moderate large values of Δr^2 can be explained by the fact that D and B in a city structure are not entirely independent from each other.

Table 3 Values of the stepwise correlation of maximum UHI intensity (ΔT) and urban surface parameters by grid cells in different periods in Szeged (n = 107)

Period	*Parameter entered*	*Multiple* $\lvert r \rvert$	*Multiple* r^2	Δr^2
March 1999 - February 2000	*D*	0.837	0.701	0.000
	B	0.877	0.769	0.068
16 April - 15 October (non-heating season)	*D*	0.861	0.742	0.000
	B	0.892	0.795	0.053
16 October - 15 April (heating season)	*D*	0.760	0.577	0.000
	B	0.816	0.666	0.089

Referring to the investigated periods *Table 4* contains the model equations which describe ΔT in the best way. The absolute values of the multiple correlation coefficients (r) between the maximum UHI intensity and the parameters are 0.837 and 0.877 for the one-year period, 0.861 and 0.892 for the non-heating season and 0.760 and 0.861 for the heating season (they all are significant at 0.1% level) (*Tables 3* and *4*). The corresponding squares of these multiple correlation coefficients (r^2) provide explanations of 70.1% and 76.9%, of 74.2% and 79.5 and of 57.7% and 66.6% of the variance, respectively.

Table 4 Best fit model equations for the average of maximum UHI intensity (ΔT) using urban surface parameters in different periods in Szeged (n = 107)

Period	*Parameters*	*Multiple linear regression equations*	*Sig. level*
March 1999 - February 2000	D	$\Delta T = -0.590D + 2.683$	0.1%
	D, B	$\Delta T = -0.466D + 0.007B + 2.016$	0.1%
16 April - 15 October	D	$\Delta T = -0.725D + 3.242$	0.1%
	D, B	$\Delta T = -0.593D + 0.008B + 2.533$	0.1%
16 October - 15 April	D	$\Delta T = -0.430D + 2.022$	0.1%
	D, B	$\Delta T = -0.315D + 0.007B + 1.406$	0.1%

CONCLUSIONS

The results indicate that statistical type of modelling of spatial distribution of maximum urban heat island, based on urban surface factors, is an appropriate process. As the correlation coefficients of the parameters show, a short distance from the city centre and a high built-up ratio, which prevail mostly in the inner parts of the city, play important roles in the increment of the urban temperature.

Consequently, our preliminary results prove that the statistical approach which determines the behaviour of the UHI intensity in Szeged is promising and this fact urge us to make more detailed investigations. We are planning to extend this project by modelling urban thermal patterns as they are affected by weather conditions with a time lag. We intend to employ the same parameters used in this study, as well as additional urban and meteorological parameters, to predict the magnitude and spatial distribution of the maximum UHI intensity on the days characterised by any kind of weather conditions (apart from the ones with precipitation) at any time of the year without recourse to extra mobile measurements. These tasks require longer-term data sets, so we intend to gather data for a period of more than one year.

The results will be of practical use in predicting the pattern of energy consumption inside the city. They can be used to forecast and plan the energy demand, particularly in cold and warm periods of the year when energy consumption of heating and cooling, respectively, is highest.

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ANALYSIS OF AIR QUALITY PARAMETERS IN CSONGRÁD COUNTY

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Összefoglalás - A tanulmány célja a légszennyező paraméterek időbeli jellemzőinek és statisztikai kölcsönhatásainak vizsgálata Szegeden és Csongrád megyében. Néhány állomás NO_2- és SO_2-koncentráció idősoraira szélsőérték modelleket illesztünk, s e modellekre alapozva kiszámítjuk a visszatérési időket, azaz a vizsgált két paraméter adott együttes maximális koncentrációit meghaladó értékek jövőbeni legkorábbi együttes bekövetkezéséig terjedő időszakokat. A dolgozatban a vizsgált állomások havi átlagos NO_2- és SO_2-koncentrációinak, valamint az ülepedő por havi összegeinek idősorait elemezzük. Az adatok - az egyes légszennyező paraméterektől függően - 1985-től állnak rendelkezésre. Az egyes idősorok szerinti trendanalízis eredményei alapján nem tudunk egyértelmű térbeli rendszert kimutatni, mivel egyrészt a szignifikáns trendek periódusai eltérő előjelűek, másrészt az azonos előjelű szignifikáns trendek periódusai eltérők. Alkalmazzuk a kétmintás t-próba egy speciális esetét is, melyet Makra fejlesztett ki. Ez a próba lehetővé teszi annak eldöntését, hogy szignifikáns eltérés van-e két nem független, normális eloszlású minta középértékei között? E próba felhasználásával végzett ún. szakadásvizsgálat szerint az ülepedő por havi összegeinek idősora szignifikáns negatív előjelű szakadást mutat az idősor végén. A vizsgált paraméterek térbeli kapcsolatait faktoranalízis segítségével elemeztük. A célunk az volt, hogy az NO_2- és SO_2-koncentrációk, valamint az ülepedő por idősorai alapján objektív alrégiókat határolhassunk körül. A légszennyezők arányai a gépjárműforgalom lényeges szerepére utalnak. A forgalom változásai jelentős mértékben hozzájárulnak a levegőminőség napi változásához.

Summary - The aim of the study is to determine partly spatial and temporal characteristics, partly statistical interrelationships concerning contaminating parameters at the town of Szeged and in Csongrád county. We also fit extreme-value models to the NO_2 and SO_2 concentrations observed at some stations and calculate return levels, which are about to be exceeded once in a given period, based on these models. Monthly averages for NO_2 and SO_2 concentrations and monthly totals for deposited particulates at given sites are analysed in this paper. Data have been available, depending on the pollutants, since at least 1985. Local trend analysis does not show a clear spatial structure among the sites since signs of significant periods are different and significant periods of the same sign are not similar among the sites. A special case of the two-sample t-test developed by Makra is also applied. This test makes it possible to determine whether or not averages of non-independent variables differ significantly. By using this test we made a so called tear analysis, according to which it was found that monthly totals of deposited dust tore considerably with negative signs at the end of the data sets. Spatial relations are analysed by factor analysis with the intention to determine objective subregions by applying data sets of NO_2, SO_2 and deposited dust. Ratios of pollutants refer definitely to the role of motor vehicle traffic. Variation of traffic contributes mostly to the change in daily air quality.

Key words: air pollutants, RIE-network, monitoring station, trend analysis, a special case of the two-sample t-test, extreme value analysis, factor analysis

INTRODUCTION

Air pollution is one of the greatest environmental problems facing mankind. In many urban areas large concentration of human activities induce considerable amounts of pollutants to be accumulated. As it is well known, the main pollution sources are motor vehicle traffic, which heavily affects air quality in densely urbanized regions, and emissions from building heating systems contribution of which is important in the winter months. Air pollution is harmful to the buildings, technical devices and may cause serious health damage, as well. The nature and importance of air quality problems depend on geographical (climate, local meteorological conditions at the moment, position, relief) and social (existing environmental regulations, urban planning choices) factors. Research of urban air has a wide literature. According to the subject of the papers the authors can make an analysis on characteristics of pollutants (e.g. *Morawska et al.*, 1998), others deal with spatial and temporal variety of those (e.g. *Hastie et al.*, 1996; *Tripathi et al.*, 1996) or investigate statistical interrelationships among variability of pollutants (e.g. *Spicer et al.*, 1996) or examine social policy on regulating emissions (e. g. *Chin*, 1996; *Fang and Chen*, 1999) or study connection of air pollution with meteorological components (e.g. *Kassomenos et al.*, 1995) or evaluate urban air quality using special methods (e.g. *Angius et al.*, 1995) and special air quality indicators (e.g. *Kassomenos et al.*, 1999).

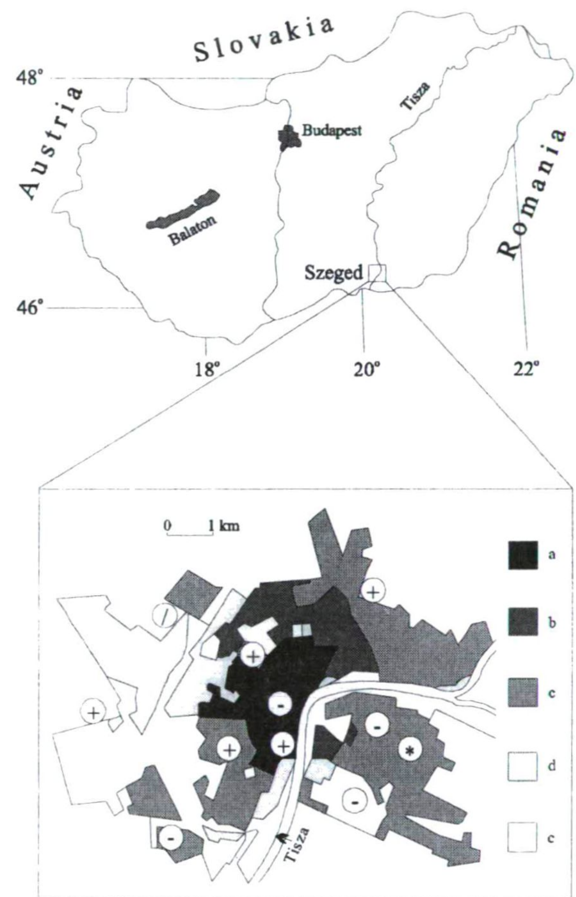


Fig. 1a Geographical position of Szeged, Hungary and built-up types of the city (*Unger*, 1997)
(a : centre (2-4-storey buildings); b: housing estates with prefabricated concrete slabs (5-10-storey buildings); c: detached houses (1-2-storey buildings); d: industrial areas; e: green areas; ∅ : automatic environmental monitoring station; + : sites of measurements for SO_2, NO_2 and deposited dust; * : site of measurements for SO_2 and NO_2 only; - : sites of measurements for deposited dust only; +, *, - : RIE-network)

The aim of the present study, considering the above mentioned classification, is complex: to determine partly spatial and temporal characteristics, partly statistical interrelationships concerning contaminating parameters and to analyze their connection with meteorological elements. The analysis is made on the data of a middle-sized town, Szeged. The analysis is made on the data sets of 9 settlements in Csongrád county (*Fig. 1b*), with special interest to the middle-sized town, Szeged, which is the largest city in the county.

GEOGRAPHICAL POSITION, METEOROLOGY AND TOPOGRAPHY OF SZEGED AND CSONGRÁD COUNTY

Szeged lies at approximately 20°06'E and 46°15'N near the confluence of the Tisza and Maros rivers. It is the largest town in the south-eastern part of Hungary. The city is flat and low (79 m above sea level), therefore its climate is free from orographical effects (*Fig. 1a*). Consequently its geographical conditions are favourable for the development of an undisturbed urban climate. The number of inhabitants of the city is up to 155,000 and the surface of its built-up area is about 46 km^2. The total urban spread extends well beyond the city limits and includes north of the town the largest oil field in Hungary with several oil torches. This oil field is a significant source of NO_x and sulfur dioxide. The power station, located in the western part of the town, and motor vehicle emissions have largely contributed to the nitrogen oxide levels in Szeged.

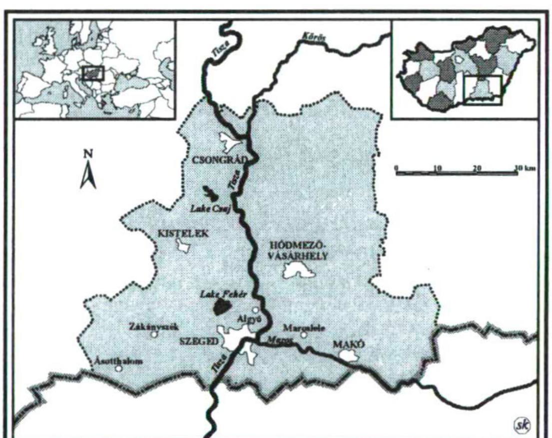


Fig. 1b Geographical position of the measuring stations in Csongrád county

Most territory of Hungary (including Csongrád county and Szeged agglomeration) are characterized in climatic classification of Köppen by *Cf* climate (temperate warm climate with quite equal distribution of precipitation amounts) or in that of Trewartha by *D.1* climate (continental climate with a long warm season). Urban air quality basically differs depending on the meteorological elements. The averages for those in Szeged region are as follows. Mean annual temperature is 11.2°C while mean January and July temperatures are -1.2°C and 22.4°C, respectively. As for yearly averages, the annual precipitation is 573 mm, the relative humidity is 71%, the windspeed is 3.2 m s^{-1}, and the sunshine duration is 2102 hours.

A detailed climatic classification for Hungary is based on the mean temperature of the growth season (t_{VS}) and the aridity index (H) (where $H = Q^*/L_v P$ and Q^* is the annual mean net radiation and L_v is the latent heat of vaporization and P is the annual mean precipitation). According to these physical climatological characteristics climate of Szeged is *warm-dry* with $t_{VS} > 17.5$°C and $H > 1.15$.

The basis of the city structure is a boulvard-avenue street system crossed by the River Tisza (*Fig. 1a*). In this way the structure of the city is simple however, following to this system, motor vehicle traffic as well as air pollution are concentrated in the city. The industrial area is located mainly in the north-west part of the town. Thus the prevailing westerly and northerly winds transport the pollutants originating from this area towards the centre of the city.

During the last decades the structure of built-up areas has been significantly modified since huge housing estates were built with prefabricated concrete slabs in the north and east outskirts. These housing estates are found between the centre and the area of detached houses (*Fig. 1a*).

There have been several papers on urban climate of Szeged (e.g. *Unger*, 1997). However, contrary to the fact that there has been operating an environmental monitoring system for more than two decades, investigations on air quality of the city have just been started (*Makra*, 1999).

In Csongrád county (besides Szeged), there have been working altogether 32 RIE-stations. From them 8 stations, distributed almost homogenously, were chosen for further investigation (Hódmezővásárhely, Csongrád, Makó, Kistelek, Ásotthalom, Algyő, Zákányszék and Maroslele) (*Fig. 1b*).

SAMPLING AND ANALYSIS

An environmental operating system has been working at Szeged since 1985 in the frame of which occasional measurements have been performed by a Regional Immission Examinating (RIE) network of station at various sites of the city for determining concentration of various pollutants (*Table 1*).

The main characteristics of pollutants measured are as follows.

Sulfur dioxide (SO_2)

There are two main sources of sulfur dioxide emission. The first results from the burning of fuel containing sulfur, such as fuel oil and industrial diesel. The other is from oil refineries and sulfuric acid manufacturing plants. Long-lasting high concentrations of SO_2 increases the frequency of respiratory deseases.

Table 1 Data basis

Measurements	*Pollutant*	*Unit*	*Measurements have been performed since*	*Number of sites*
RIE-network	SO_2	$\mu g\ m^{-3}$	1988 -	9
	NO_2	$\mu g\ m^{-3}$	1988 -	9
	soot	$\mu g\ m^{-3}$	in 1992, only	2
	fine suspended particulates	$\mu g\ m^{-3}$	1987 -	12
	deposited particulates	$g\ m^{-2}$ month	1985 -	10
monitoring station	CO, NO, NO_2, NO_x (= NO + NO_2), O_3, SO_2, fine suspended particulates	$\mu g\ m^{-3}$	August 1, 1996	1

Nitrogen oxides (NO, NO_2 and NO_x(=NO+NO_2))

Major sources of these pollutants are fuel burning equipments and vehicle exhaust.

Ozone (O_3)

In tropospheric background air ozone partly comes from photolysis of NO_x and interaction of various organic compounds. As it is known for some conditions the process of ozone formation is controlled almost entirely by NO_x and is largely independent of VOC, while for other conditions ozone production increases with increasing VOC and does not increase (or sometimes even decreases) with increasing NO_x. However it has been difficult to determine whether ozone production during specific events is associated with NO_x-sensitive chemistry or VOC-sensitive chemistry. For analyzing interrelationships between ozone, NO_x and VOC a model was established (*Sillman,* 1999).

Carbon monoxide (CO)

The main source of CO is motor vehicle emission. Others come from incomplete combustion of fuels and cigarette smoke.

Dust

Dust, together with suspended particles and smoke, belongs to the group of pollutants named particulate matter (PM). Suspended particles and smoke, which are smaller and lighter, are of greater importance. These reamin in the atmosphere longer and affect a larger area. The effects of dust particles (being larger and heavier) are more localized and they settle quickly. The main sources of particulate matter, in this way that of dust, are motor vehicles, construction activities and fuel burning equipments such as boilers and furnaces.

Samplings for SO_2 and NO_2 have been performed by AEROMAT OH-601 instruments while analysis of the samples has been occurred by using an automatic analitical instrument named CONTIFLO. Soot and fine suspended particulates were collected on filters by using KS-303 and KS-303 150.10 instruments while deposited particles on plastic pots.

The automatic environmental monitoring station is situated in the downtown, about 15 m away from a busy highway. It measures, besides the pollutants mentioned above, climatic elements (air temperature, humidity, radiation, pressure, precipitation, wind speed and wind direction), as well.

Analysis of occasional measurements performed at various sites of the city is quite difficult because of the unsystematic collection of data. Measurements were performed not every day even at some sites there are considerable lack of data. In order to keep information being available in data, monthly averages of pollutants were calculated if at least ten measurements for a given pollutant were performed in a month. If there were less than ten measurements, the pollutant was taken out of consideration in the given month. By using monthly averages, lack of data was reduced. Even though there are no monthly averages of SO_2 and NO_2 concentrations between October 1997 and March 1998 at the site Tarján and in October 1997 and between June and December 1998 at the site Ironworks. Data of soot are so much incomplete that it was impossible to make a detailed analysis of them. Deposited particulates have the most complete data series, however each site has some shortage of data and even there were no measurements at the site House of Young Guards between July 1995 and December 1998. Because of absence of data, monthly mean concentrations of SO_2 and NO_2 (sites: Szeged University Colloidics, Tarján district, Ironworks and Tavasz street) are analyzed between 1995 and 1998. Monthly totals of deposited dust are almost complete for the period between 1985-1998 (ten sites). Incomplete data sets of fine suspended dust makes it impossible to perform a detailed analysis, therefore this parameter was taken out of consideration from further investigations (*Fig. 1a*).

There are also some absence of data at the automatic environmental station (*Table 2*). However pollutants mentioned in *Table 2* are all drawn into the analysis.

Table 2 Lack of data at the automatic environmental station, in percentage of days of the year

pollutant / *year*	CO	NO_x	O_3	SO_2	*dust*
1997	7.7	32.3	5.8	93.4	12.1
1998	9.6	9.3	21.1	9.6	26.0
1999	0.3	3.3	1.4	0.0	25.8

METHOD

Trend analysis

Significancy of linear trends during any subperiod within a data series of given length is checked by Student's t-test, as follows. Let us have the variable of Student distribution,

$$t = (b - \beta) / s_b \qquad (1)$$

where β - the real (unknown) regression coefficient,

b - empirical regression coefficient, estimated from the finite sample,

s_b - standard deviation of the empirical estimate from the regression coefficient, b.

The zero-hypothesis is that $b = \beta = 0$, i.e. the empirical regression b does not significantly differ from 0. The statistical decision concerning this hypothesis is performed on the basis of the knowledge of the t-distribution (included into tables, in practice). The following analysis of the significance is performed at the 1% significance level, considering that the appropriate degree of freedom is n - 2 , where n is the number of elements in the sample. If the t-value calculated by (1) is higher than the given threshold of the t-distribution, we consider b to be significantly different from 0. Otherwise, it is not. This test has been performed for all possible 3, ..., n years subperiods for the given samples.

A special case of the two-sample t-test

A new statistical test is developed by *Makra* for determining if there is significant difference between expected values of non-independent time series (*Makra et al.*, 2000a).

The developed expression $\dfrac{\overline{M} - \overline{m}}{\sqrt{\dfrac{N-n}{N \cdot n}} \cdot \sigma}$ is a probability variable with N(0;1) distribution.

Now, from the table of the distribution function of the standard normal distribution, it can be determined that x_p to a given $0 < p < 1$ number for which:

$$P\left(\left|\frac{\overline{M} - \overline{m}}{\sqrt{\frac{N-n}{N \cdot n}} \cdot \sigma}\right| > x_p\right) = p \qquad (2)$$

If the absolute value of the above probability variable with N(0;1) distribution is higher than x_p then it is said that $\overline{M}$ and $\overline{m}$ differ significantly. The 0-hypothesis, according to which there is no difference between $\overline{M}$ and $\overline{m}$, is realized not more than at the critical p probability.

Significance-tests are carried out at $p = 0.01$ probability level.

Extreme value distributions

The essence of the theory is that if we have a sequence of independent, identically distributed observations, and take their (suitably normalised) maxima, then in most cases it can be approximated by an extreme value distribution. Therefore, if we have a long data series coming from any reasonable distribution (see for example 1 for the exact conditions), then the above-mentioned three parameters can be estimated. The estimation can be based either on the annual (monthly, bi-weekly, etc) maxima or on the highest *k* values (for a summary of the methods, see *Reiss and Thomas,* 1997).

The extreme value distributions form a three-parameter family. Two of them are the shift and scale parameters, which only determine the expected value and the standard deviation of the distribution; while the third one is the so-called „shape" parameter, which has a major effect on the shape of the distribution. This parameter determines if there is finite right or left endpoint of the distribution, as well as the number of existing moments of the distribution. Consequently, if any extreme value distribution is fitted to a given data series, then the abovementioned three parameters should be estimated (*Weissman,* 1977; *Embrechts,* 1997.).

Regionalisation by factor analysis

One of the best methods of studying time series data for a large number of stations or grid points, where strong spatial and temporal correlation prevails, is *factor analysis* (see e.g. *Bartzokas and Metaxas,* 1993). One of the main benefits of this method is the reduction of the initial variables to much fewer uncorrelated ones, namely the factors. In this way, regions can be defined where, for any point within each region, the analysed meteorological variable covaries. Each original variable, P_i, i = 1, 2,..., n, can be expressed as $P_i = a_{i1}F_1 + a_{i2}F_2 + ... + a_{im}F_m$ (m < n), where F_j, j = 1, 2, ..., m, are the factors and a_{ij} are the loadings. One important stage of this method is the decision for the number (m) of the retained factors. On this matter, many criteria have been proposed. In this study the *Guttman criterion* or *Rule 1* is used which determines to keep the factors with eigenvalues > 1 and neglect the ones that do not account for at least the variance of one standardized variable. Another vital stage in this analysis is the so-called rotation of the axes (factors). This process achieves a discrimination among the loadings which makes the rotated axes easier to interpret. In this analysis the *Orthogonal Varimax Rotation* has been applied, which keeps the factors uncorrelated. In general, there is no guarantee that the evaluated factors represent dynamically existing entities, but, as with any statistical tool, it is important to determine whether the results have any physical meaning.

RESULTS AND DISCUSSION

On the basis of the local trend analysis our findings are as follows. Linear trends of monthly amounts of deposited dust (μg m^{-2}) and that of NO_2 concentrations show significant trends both for relatively short (7-23 months) and quite long (102-137 months) sequences. It is also remarkable that the number of significant trends is at some stations 1 or 2, while at other stations 4 or 5. For the longer sequences, the interannual variance is too high to allow significance of monotonous linear changes in the local series. In the table, sequence of significant periods is set in diachronic order. If comparing signs of significant periods, one can establish that they are completely different at the sites. Significant periods of the same sign are not much similar among the sites. This means that short sequences are yielded rather by random interannual fluctuations, than by the long-term trends (*Table 3a-b*).

Table 3a Subperiods with significant trends of deposited dust in 1985-1998; year, month (m)

Teachers' Training College	*Tarján district*	*Iron-works*	*Esperanto street*	*Bécsi Boulevard*	*State Service for Health Control, New Szeged*	*Nurses' Training School, New Szeged*	*Széchenyi square*	*Mátyás square*
1986.07.- 1994.02. 102 m (+)	1985.03.- 1996.07. 137 m (-)	1987.12- 1990.06. 51 m (+)	1989.11.- 1998.09. 106 m (+)	1985.01.- 1998.03. 159 m (-)	1985.11.- 1987.08. 22 m (-)	1986.12.- 1988.06. 19 m (+)	1986.03.- 1989.03. 37 m (-)	1985.01.- 1988.07. 43 m (-)
1988.02.- 1998.05. 124 m (-)	1989.09.- 1998.08. 108 m (+)	1988.04.- 1992.10. 55 m (-)		1989.12.- 1992.04. 59 m (+)	1994.04- 1995.01. 10 m (-)	1989. 04.- 1994.07. 64 m (+)	1990.09.- 1992.09. 25 m (+)	
		1991.09.- 1995.12. 52 m (+)		1992.10.- 1994.10. 25 m (+)	1994.09.- 1998.01. 41 m (+)	1993.06.- 1998.12. 67 m (-)	1994.03.- 1995.03. 13 m (-)	
		1995.08.- 1997.02. 19 m (-)		1992.12.- 1993.07. 8 m (+)			1997.02.- 1997.08. 7 m (-)	
		1996.02.- 1997.12. 23 m (+)		1996.01.- 1996.08. 8 m (+)				

Table 3b Subperiods with significant trends of NO_2 concentrations in 1995-1998; year, month (m)

Szeged University, Colloidics	*Tarján district*	*Ironworks*	*Esperanto street*	*Bécsi Boulevard*	*House of Parties*
1991.01.- 1992.06. 18 m (-)	1991.06.- 1991.12. 7 m (-)	1991.01.- 1993.11. 36 m (+)	1991.02.- 1991.11. 10 m (-)	1991.01.- 1993.11. 35 m (-)	1991.10.- 1993.03. 18 m (+)
1991.07.- 1993.12. 30 m (+)	1992.10.- 1993.02. 5 m (+)		1991.07.- 1993.04. 22 m (+)		1993.02.- 1993.06. 5 m (-)
			1992.02.- 1992.05. 4 m (-)		
			1993.01.- 1993.07. 7 m (-)		

Table 3c Subperiods with significantly different averages of deposited dust from that of the full data set in 1985-1998; year, month (m)

Teachers' Training College	*Tarján district*	*Iron-works*	*Esperanto street*	*Bécsi Boulevard*	*State Service for Health Control, New Szeged*	*Nurses' Training School, New Szeged*	*Széchenyi square*	*Mátyás square*
1985.03.- 1996.11. 141 m (+)	1985.03.- 1986.07. 17 m (+)	1986.04.- 1990.04. 49 m (+)	1985.03.- 1985.11. 9 m (+)	1985.02.- 1989.10. 57 m (+)	1992.06.- 1993.02. 9 m (+)	1985.03.- 1995.05. 123 m (+)	1988.03.- 1989.04. 14 m (+)	1988.09.- 1989.11. 15 m (+)
1990.11.- 1998.11. 97 m (-)	1986.07.- 1997.03. 129 m (-)	1989.11.- 1997.04. 91 m (-)	1986.01.- 1997.01. 133 m (-)	1989.11.- 1998.03. 101 m (-)		1989.04.- 1998.12. 117 m (-)	1989.06.- 1996.10. 89 m (-)	1989.02.- 1992.08. 43 m (+)
	1997.07.- 1998.07. 13 m (+)		1989.02.- 1989.08. 7 m (+)				1997.01.- 1997.06. 6 m (+)	1998.02.- 1998.06. 5 m (+)
			1997.02.- 1998.08. 19 m (+)					

Table 3d Subperiods with significantly different averages of NO_2 concentrations from that of the full data set in 1995-1998; year, month (m)

Szeged University, Colloidics	*Tarján district*	*Ironworks*	*Esperanto street*	*Bécsi Boulevard*	*House of Parties*
1991.01.- 1991.05. 5 m (+)	1991.04.- 1991.09. 6 m (+)	1991.01.- 1992.11. 23 m (-)	1992.09.- 1993.05. 9 m (+)	1991.01.- 1992.03. 15 m (+)	1991.05.- 1992.05. 13 m (-)
1991.04.- 1993.10. 31 m (-)		1992.08.- 1993.12. 17 m (+)		1991.04.- 1993.12. 33 m (-)	1992.06.- 1993.04. 11 m (+)

As for the application of the special case of the two-sample t-test, subperiods were identified averages of which are significantly different from the mean of the data series examined. Concentrations of pollutants in these subperiods were much higher or lower than that. The point of the method is to determine the start and the termination of the significant periods. This is done for date for which the significance is still valid, irrespectively to that, which years would yield the strongest difference (i. e. among the significant ones). This search has been performed by a special case of two-sample t-test, applied to detect differences between averages of non-independent data sets (*Makra and Horváth,* 1999; *Makra et al.,* 2000b). The significance tests have been performed at the 1% significance level (*Table 3c-d*). In the table, sequence of significant periods is defined in diachronic order.

The following results can be established. In the data sets of deposited dust, the signs of the most long-term periods (91-133 months) are negative which refer to the fact that at seven sites from the nine the amount of deposited dust decreased significantly. The experienced similarity among the long-term anomalies of identical sign at the sites suggest that these long sequences are already yielded the long-term trends. Significant subperiods in the data sets of NO_2 concentrations do not show a clear tendency. At some stations they have positive sign while at other ones, even for the same period, they are negative.

Since not only one measuring station is working at the examined settlements, data maximum of all stations was considered for a given settlement every day. NO_2 and SO_2 data series for the examined settlements, received in this way, are shown in *Fig. 2a-i* and *Fig. 3a-i*. One can see that these data are incomplete and comparison between data series of the examined settlements promises to be very difficult, since periods with lack of data are different. At some cases there might be even incorrect values in the data series (very high values).

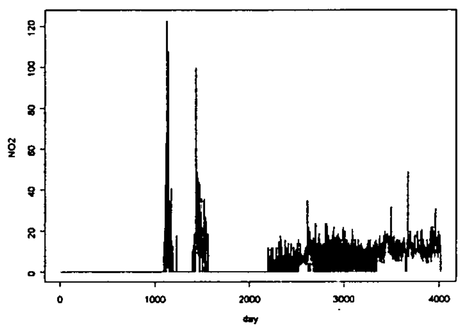


Fig. 2a NO_2 data series for Szeged, received by taking daily maxima of all stations at Szeged, $\mu g\ m^{-3}$

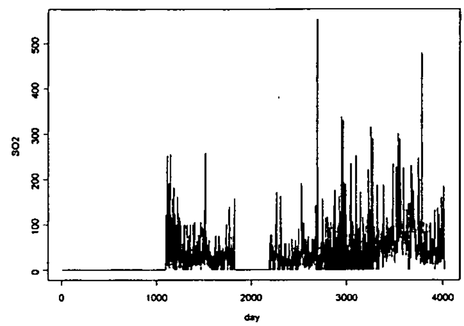


Fig. 3a SO_2 data series for Szeged, received by taking daily maxima of all stations at Szeged, $\mu g\ m^{-3}$

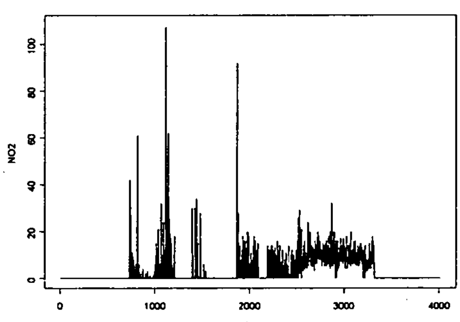


Fig. 2b NO_2 data series for Hódmezővásárhely, received by taking daily maxima of all stations at Hódmezővásárhely, $\mu g\ m^{-3}$

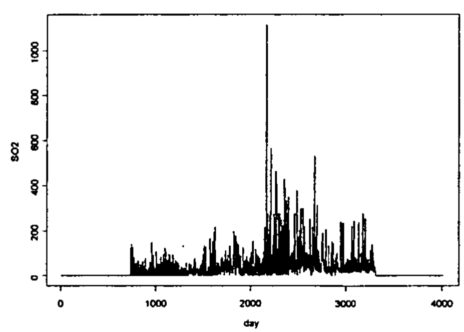


Fig. 3b SO_2 data series for Hódmezővásárhely, received by taking daily maxima of all stations at Hódmezővásárhely, $\mu g\ m^{-3}$

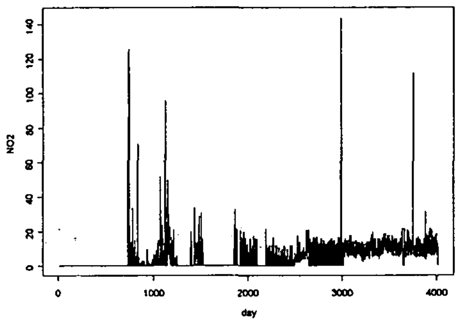


Fig. 2c NO_2 data series for Csongrád, received by taking daily maxima of all stations at Csongrád, μg m^{-3}

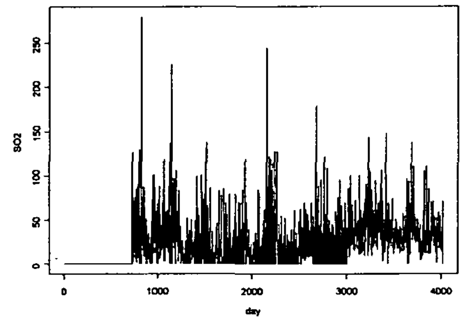


Fig. 3c SO_2 data series for Csongrád, received by taking daily maxima of all stations at Csongrád, μg m^{-3}

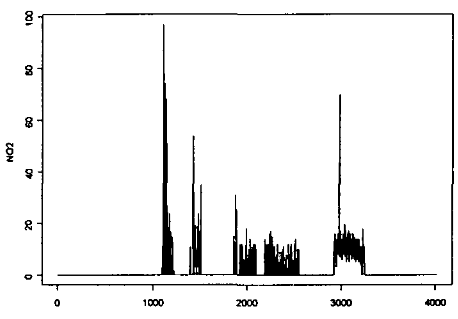


Fig. 2d NO_2 data series for Makó, received by taking daily maxima of all stations at Makó, μg m^{-3}

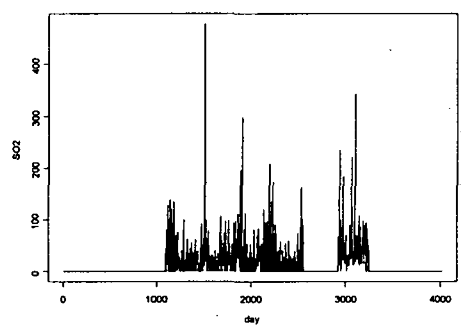


Fig. 3d SO_2 data series for Makó, received by taking daily maxima of all stations at Makó, μg m^{-3}

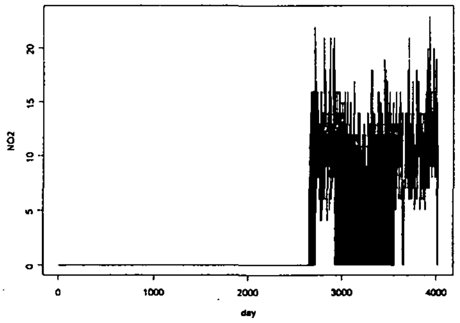


Fig. 2e NO_2 data series for Kistelek, received by taking daily maxima of all stations at Kistelek, μg m^{-3}

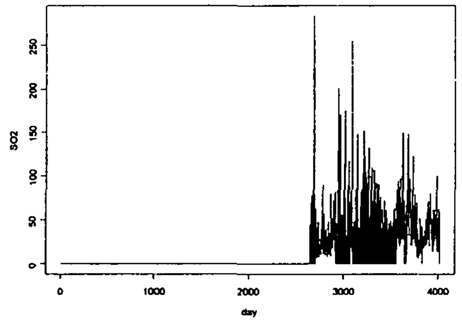


Fig. 3e SO_2 data series for Kistelek, received by taking daily maxima of all stations at Kistelek, μg m^{-3}

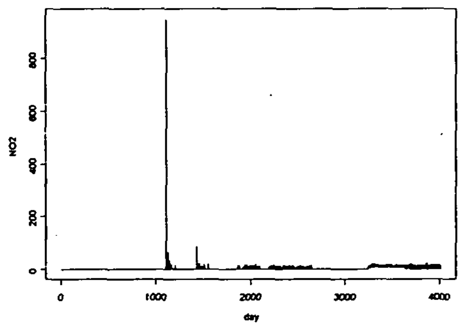


Fig. 2f NO_2 data series for Ásotthalom, received by taking daily maxima of all stations at Ásotthalom, μg m^{-3}

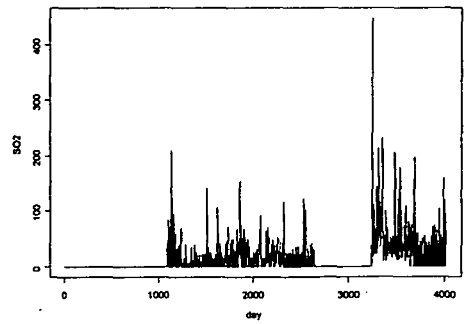


Fig. 3f SO_2 data series for Ásotthalom, received by taking daily maxima of all stations at Ásotthalom, μg m^{-3}

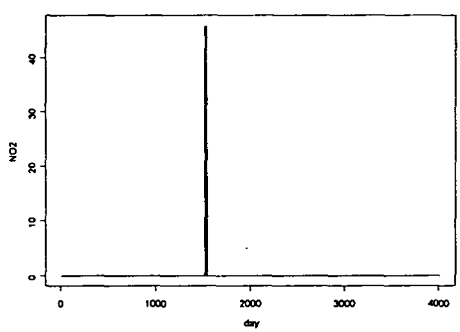


Fig. 2g NO_2 data series for Algyő, received by taking daily maxima of all stations at Algyő, μg m^{-3}

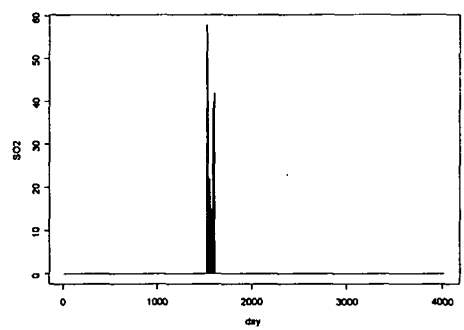


Fig. 3g SO_2 data series for Algyő, received by taking daily maxima of all stations at Algyő, μg m^{-3}

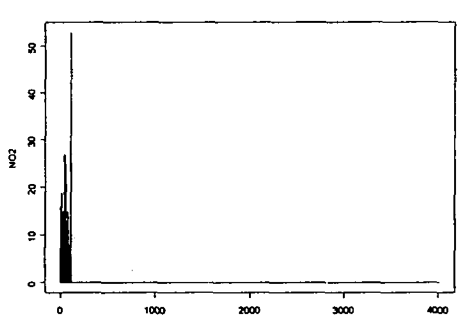


Fig. 2h NO_2 data series for Zákányszék, received by taking daily maxima of all stations at Zákányszék, μg m^{-3}

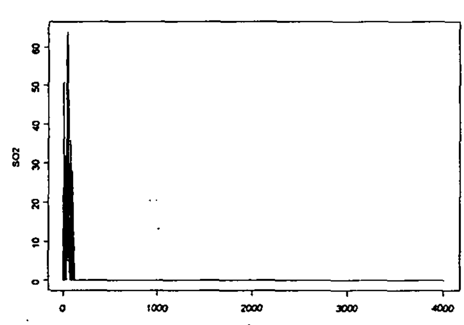


Fig. 3h SO_2 data series for Zákányszék, received by taking daily maxima of all stations at Zákányszék, μg m^{-3}

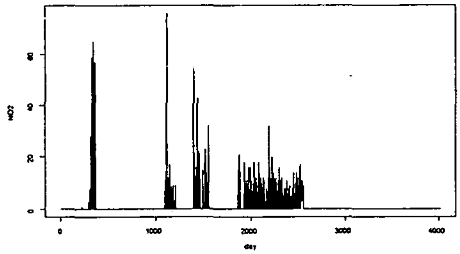


Fig. 2i NO_2 data series for Maroslele, received by taking daily maxima of all stations at Maroslele, μg m^{-3}

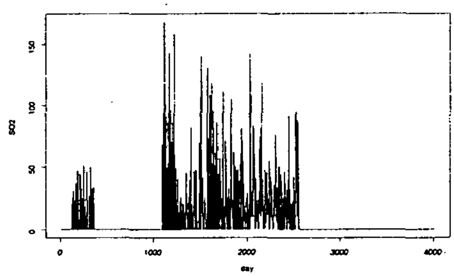


Fig. 3i SO_2 data series for Maroslele, received by taking daily maxima of all stations at Maroslele, μg m^{-3}

Afterwards, bi-weekly maxima of the abovementioned data series were calculated. In this way, the data series were contracted both in space and time. This procedure was important to perform, in order to eliminate lack of data. Namely, NO_2 was measured one day and SO_2 the other day at most of the measuring stations. However, long enough and unbroken data series were not received even in this way. Consequently, data series being at disposal, were simply pushed together (*Fig. 4a-g, Fig. 5a-g*), implicitly assuming the stationarity of the series.

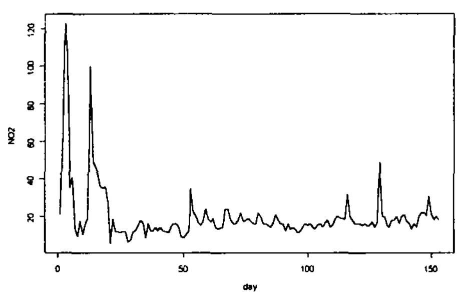


Fig. 4a NO_2 data series for Szeged; bi-weekly unbroken maxima derived from *Fig. 2a*, μg m^{-3}

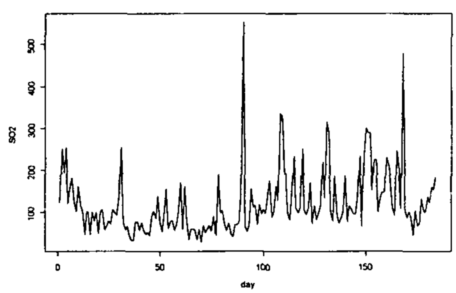


Fig. 5a SO_2 data series for Szeged; bi-weekly unbroken maxima derived from *Fig. 3a*, μg m^{-3}

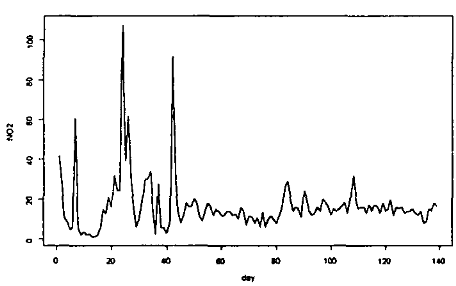


Fig. 4b NO_2 data series for Hódmezővásárhely; bi-weekly unbroken maxima derived from *Fig. 2b*, μg m^{-3}

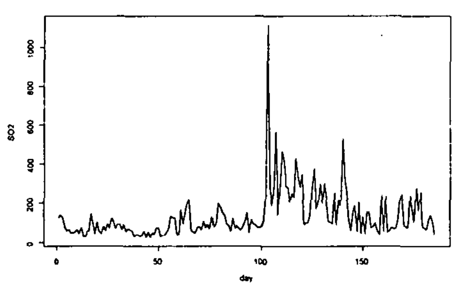


Fig. 5b SO_2 data series for Hódmezővásárhely; bi-weekly unbroken maxima derived from *Fig. 3b*, μg m^{-3}

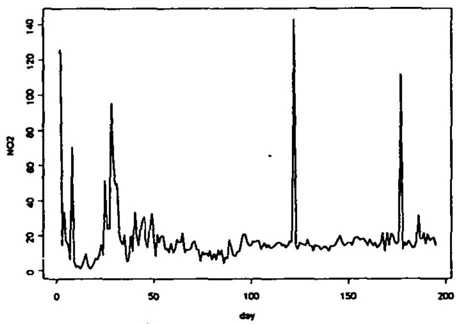


Fig. 4c NO_2 data series for Csongrád; bi-weekly unbroken maxima derived from *Fig. 2c*, µg m^{-3}

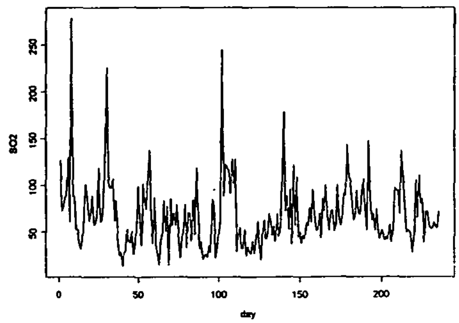


Fig. 5c SO_2 data series for Csongrád; bi-weekly unbroken maxima derived from *Fig. 3c*, µg m^{-3}

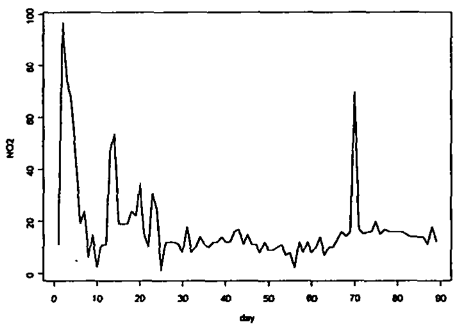


Fig. 4d NO_2 data series for Makó; bi-weekly unbroken maxima derived from *Fig. 2d*, µg m^{-3}

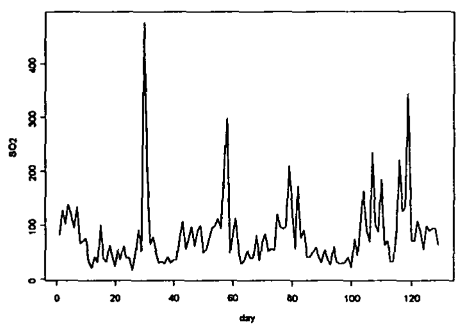


Fig. 5d SO_2 data series for Makó; bi-weekly unbroken maxima derived from *Fig. 3d*, µg m^{-3}

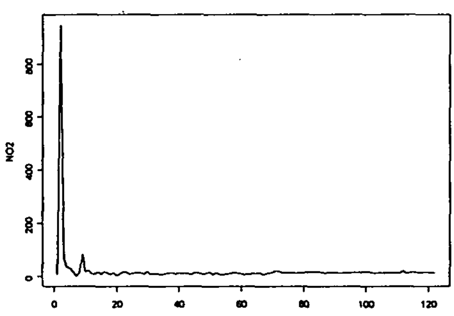


Fig. 4f NO_2 data series for Ásotthalom; bi-weekly unbroken maxima derived from *Fig. 2f*, µg m^{-3}

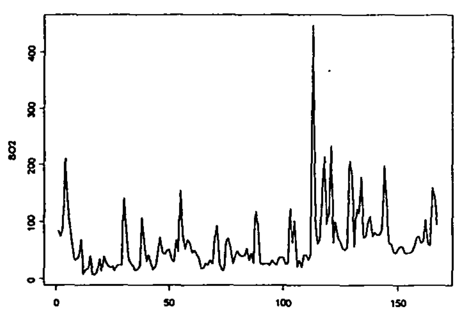


Fig. 5f SO_2 data series for Ásotthalom; bi-weekly unbroken maxima derived from *Fig. 3f*, µg m^{-3}

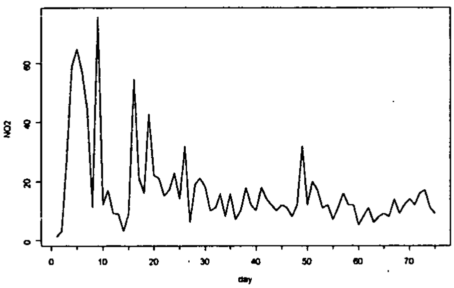


Fig. 4g NO_2 data series for Maroslele; bi-weekly unbroken maxima derived from *Fig. 2i*, μg m^{-3}

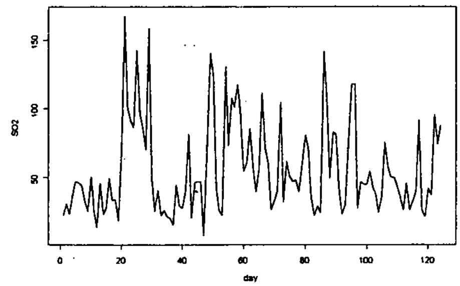


Fig. 5g SO_2 data series for Maroslele; bi-weekly unbroken maxima derived from *Fig. 3i*, μg m^{-3}

After that, autocorrelations of bi-weekly unbroken maxima for Szeged (*Fig. 6a-b*) and Maroslele (*Fig. 7a-b*) were analysed. It is evident that even these data series can not be considered totally independent.

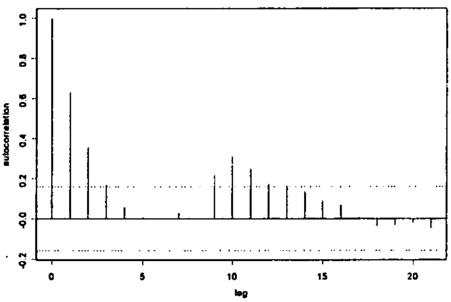


Fig. 6a Autocorrelations of the bi-weekly unbroken maxima for Szeged, NO_2, μg m^{-3}. (Confidence interval is 95%.)

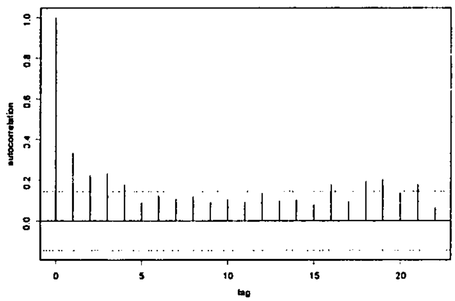


Fig. 6b Autocorrelations of the bi-weekly unbroken maxima for Szeged, SO_2, μg m^{-3}. (Confidence interval is 95%.)

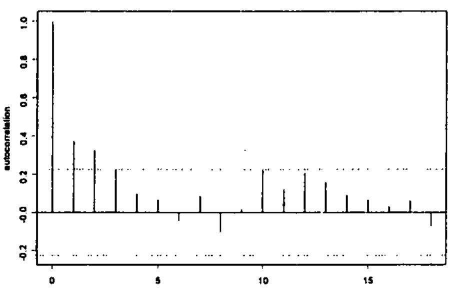


Fig. 7a Autocorrelations of the bi-weekly unbroken maxima for Maroslele, NO_2, μg m^{-3}. (Confidence interval is 95%.)

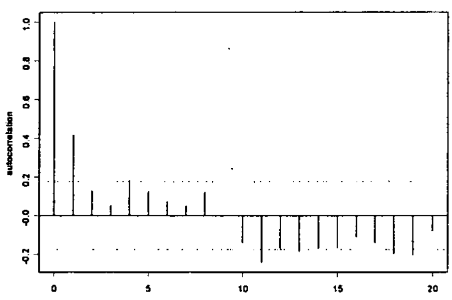


Fig. 7b Autocorrelations of the bi-weekly unbroken maxima for Maroslele, SO_2, μg m^{-3}. (Confidence interval is 95%.)

Further on, considering the data series of the bi-weekly unbroken maxima independent with the same distribution, extreme value distributions were fitted to them, by the statistical procedures described in (*Reiss and Thomas,* 1997).

Extreme value distributions were fitted to both NO_2 and SO_2 data series of Szeged and 5 further settlements in Csongrád county.

As a general experience, this family of distributions was a poor fit to NO_2 data series (*Fig. 8a*), while it was a good fit to those of SO_2 (*Fig. 8b*).

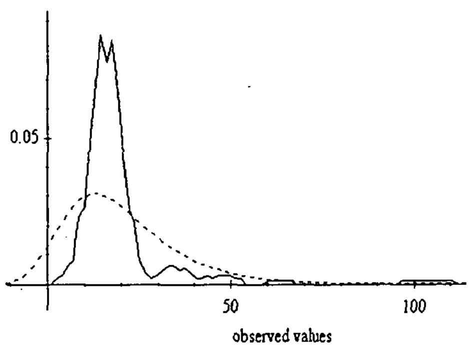


Fig. 8a Smoothed empirical density function of the bi-weekly maxima (unbroken line) and density function of the extreme value distribution fitted to that (dotted line), Szeged, NO_2. (The fit is poor, cause of which might be the irregular pattern of very high values of the data series.)

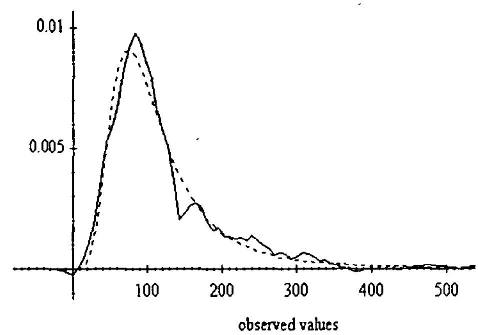


Fig. 8b Smoothed empirical density function of the bi-weekly maxima (unbroken line) and density function of the extreme value distribution fitted to that (dotted line), Szeged, SO_2. (The fit is good.)

The shape parameter of the extreme value distribution can change depending on how many extreme values of the data series are used (*Fig. 9*). From *Fig. 9* it can be seen that the estimation is jumping upside down and that the figure has no any stable horizontal part. Consequently, no any reliable estimations of the return levels can be taken for the NO_2 series. (Return level, corresponding to a given time period is the value, which is expected to be exceeded in the given time period only once.)

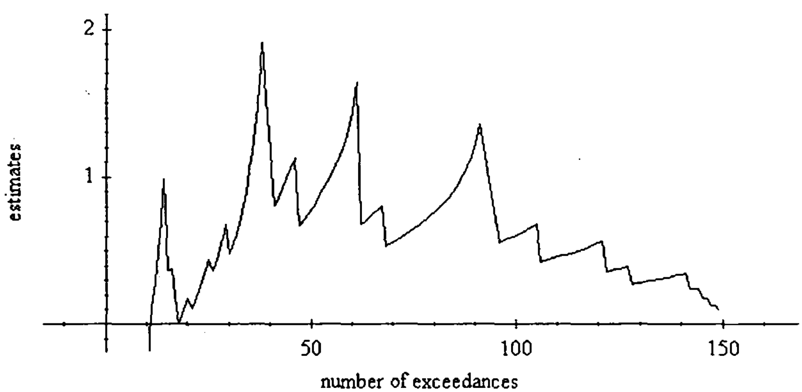


Fig. 9 Estimation of the shape parameter of the extreme value distribution, depending on the number of extreme values are used for the estimation, Szeged, NO_2

As it has already been reported, fitting was unacceptable for NO_2 data series at each examined settlements (*Fig. 9*). Findings on unreliability of estimations are illustrated by the following example. At Csongrád station there were 190 values at disposal. First, extreme value distribution was fitted to these starting data, then the data set of maxima coming from the consecutive four-element blocks were formed. In this way, 47 values were only obtained; however, it was supposed that a better fitting would be received for them. Nevertheless, it was not the case; the two estimations differed very much, which is represented in *Table 4*. Positive shape parameters correspond to distributions with infinite right-endpoint. The larger the value of gamma, the heavier the tail of the distribution, for example the moments are finite up to $1/\gamma$.

Table 4 Estimators for the shape parameter and some return levels, Csongrád, NO_2

Data series	***Gamma***	***Return levels to the periods***		
		2 years	***4 years***	***10 years***
original	0.19	52.6	63.6	80.6
maxima of four-element blocks	0.70	133.2	221.1	425.5

Contrary to the results for NO_2, extreme value distributions fit very well to smoothed empirical density functions of SO_2 data series (*Fig. 8a-b*). In the latter case, estimating parameters and return periods in two different ways, very similar results were received. E.g. for Csongrád station, on the basis of 230 starting observations, results are as follows (*Table 5*).

Table 5 Estimators for the shape parameter and some return levels, Csongrád, SO_2

Data series	***Gamma***	***Return levels to the periods***		
		2 years	***4 years***	***10 years***
original	0.08	165.9	190.1	224.0
maxima of four-element blocks	0.10	165.9	195.8	238.0

Estimations for SO_2 data series at the examined 6 stations are summarized in *Table 6*. Estimations for Hódmezővásárhely seem to be too high.

Table 6 Estimators for the shape parameters and some return levels, SO_2

Settlement	***Number of data***	***Gamma***	***Return levels to the periods***		
			2 years	***4 years***	***10 years***
Szeged	180	0.25	364.1	449.9	588.8
Maroslele	120	0.23	174.0	213.9	277.5
Makó	120	0.35	290.9	379.2	533.5
Hódmezővásárhely	180	0.46	594.8	829.8	1280.4
Csongrád	230	0.08	165.9	190.1	224.0
Ásotthalom	160	0.33	237.1	307.5	428.3

Factor analysis defined different numbers of subareas for the concentration of NO_2, SO_2 and deposited dust in the total, summer half-year and winter half-year data sets. (For the concentration of SO_2 only the winter half-year data set was submitted to factor analysis since the other two ones were incomplete.) The eigenvalues and the percentages explained by the retained and rotated factors are shown in *Table 7*. It is found that the retained factors explain 71-87% of the total variance exhibited by all initial variables. The number of retained factors varies between 2 and 4. Two subregions are found both for SO_2 and NO_2 concentrations in the winter half-year, locations of which are very similar. The map of the rotated factor loadings for NO_2 concentrations in the summer half-year shows three subregions which are different from those in the winter half-year. Maps for deposited dust are totally different from those for NO_2 and SO_2 concentrations. On the maps for deposited dust the analysis yields four subregions in the summer half-year and three in the winter half-year, even these last maps differ substantially from each other (*Fig. 10a-g*).

The method of factor analysis derives the regions from similarities and differences on given time scales. In some cases the regions differ considerably, in other cases they show great similarity (*Fig. 10a-g*). Central parts of the subregions are indicated by the 0.8 factor loading isolines. The regions are perhaps realistic in statistical sense. This means, that they are not direct consequences of the method, itself.

Table 7 The significant eigenvalues and the total percentage of variance explained by the retained and rotated factors

Pollutant	*SO_2*			*NO_2*			*Deposited dust*		
Eigen-values	*Year*	*Summer half-year*	*Winter half-year*	*Year*	*Summer half-year*	*Winter half-year*	*Year*	*Summer half-year*	*Winter half-year*
1	-	-	3.4	2.9	2.5	3.4	2.8	1.8	4.1
2	-	-	1.6	1.3	1.6	1.5	1.2	1.4	1.2
3	-	-			1.1		1.0	1.2	1.0
4	-	-						1.1	
expl. var.,%	-	-	83	71	87	81	45	61	60

Based on the annual, summer and winter half-year average ratios of various pollutants and surrounding pollution sources the characteristics of the automatic environmental monitoring station can be summarized as follows (*Table 8*). The station is located near to a highway. Consequently CO averages are high for the whole year and the summer and winter half-years. As SO_2/CO ratio is far less than 1, it shows that there are no factories near to the station discharging SO_2. Whereas in the surroundings of the station there are no typical industrial areas, the NO_x/CO ratio is low. Since the NO/NO_2 ratio is no greater than 1, it means that the station is without being significantly influenced by pollution sources from traffic. Small PM(μg m^{-3})/CO(ppdm) ratio (far less than 1) indicates that PM sources are highly related to vehicles' activities (*Fang and Chen,* 1999). Considering the results, there are no significant differences except for the NO/NO_2 ratio in 1998 and the CO concentration in 1997 and 1998, respectively. In the winter half-year the values of the above mentioned parameters are double than those in the summer half-year.

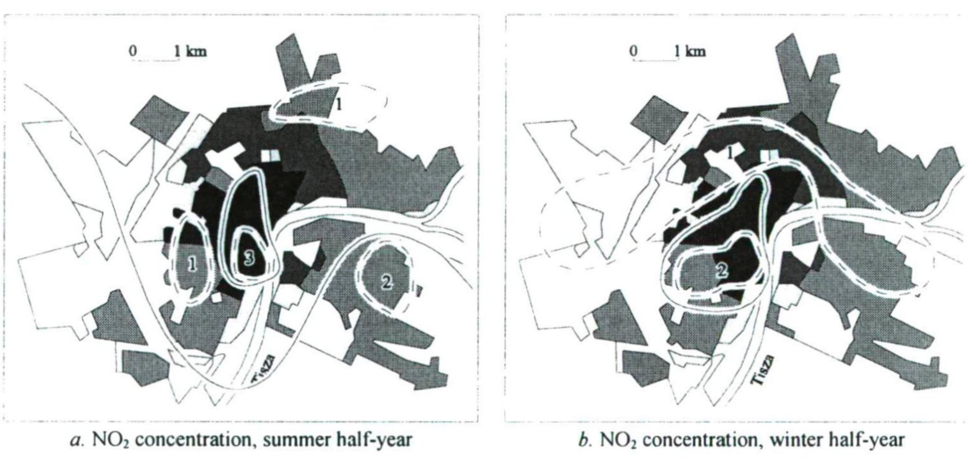
A study was conducted to investigate the difference in concentration of pollutants between weekday and non-weekday (including Saturday, Sunday and holiday) by using the 1997 and 1998 data from the automatic environmental station. In Hungary working time is 44 hours per week. It is speculated that the air quality might change during the weekend. It was found that the variation of traffic contributed mostly to the change in daily air quality. The results coming from the automatic environmental station also indicated that the daily average concentration of SO_2, CO, NO_x, NO, NO_2 and PM all increased in weekdays and decreased during the weekend (*Table 9a-c*). However, the O_3 daily average exhibited the opposite trend, it increased on Saturdays, Sundays and holidays but decreased on weekdays. The findings regarding O_3 level might indicate that the monitoring station is located near to a highway. Therefore the reaction between O_3 and NO is fast. O_3 increases as NO decreases on Saturdays, Sundays and holidays and vice versa (*Fang and Chen,* 1999).

Table 8 Annual, summer- and winter half-year averages of SO_2/CO, NO_x/CO, NO/NO_2, PM/CO ratios and those of CO in 1997, 1998 and 1999* at the automatic station

Period	***SO_2/CO***			***NO_x/CO***			***NO/NO_2***		
	1997	***1998***	***1999***	***1997***	***1998***	***1999***	***1997***	***1998***	***1999***
year	0.022	0.010	0.011	0.077	0.107	0.093	0.385	0.517	-
Apr-Sept	-	0.008	0.008	0.092	0.123	0.088	0.311	0.325	-
Oct-March	0.016	0.010	0.013	0.081	0.103	0.097	0.453	0.669	-

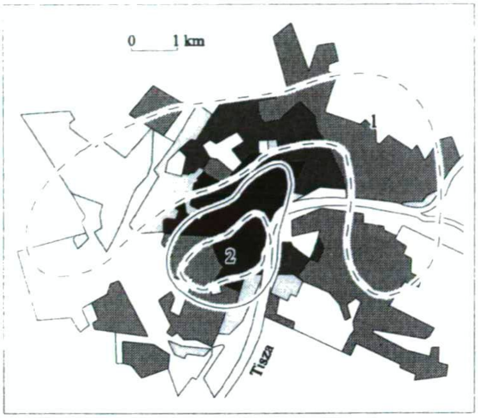
Period	***PM/CO***			***CO***		
	1997	***1998***	***1999***	***1997***	***1998***	***1999***
year	0.071	0.076	0.083	5188	5216	4188
Apr-Sept	0.098	0.099	0.100	3214	3462	3087
Oct-March	0.061	0.063	0.072	6900	6660	5288

*SO_2, NO_x (NO, NO_2), PM in $\mu g\ m^{-3}$, CO in ppdm

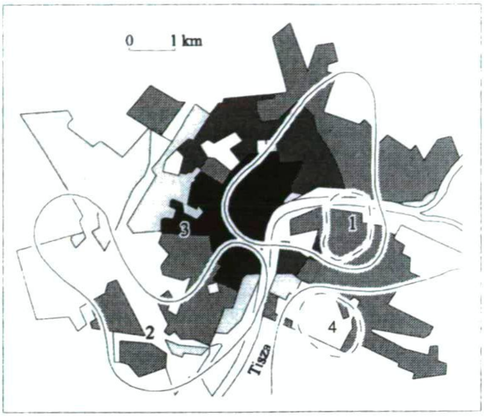


a. NO_2 concentration, summer half-year *b.* NO_2 concentration, winter half-year

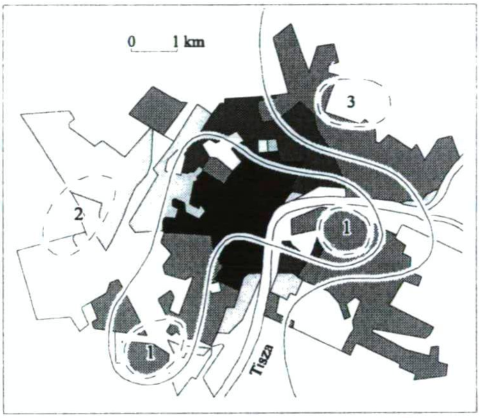
Fig. 10a-g Subareas formed according to the rotated factor loadings when the number of retained factors is > 1. Isopleths of loadings 0.8 or higher are indicated.



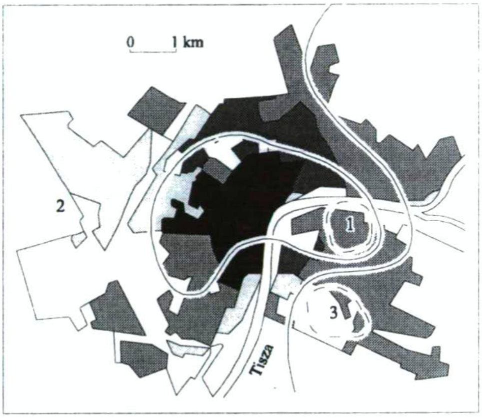
c. NO_2 concentration, year



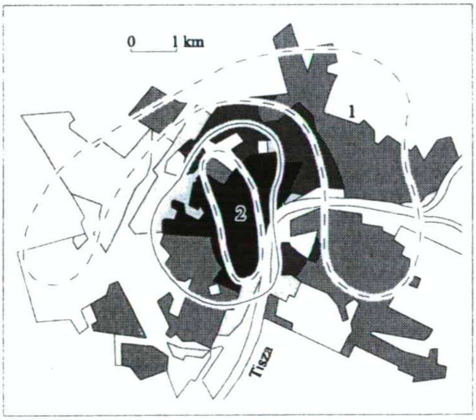
d. concentration of deposited dust, summer half-year



e. concentration of deposited dust, winter half-year



f. concentration of deposited dust, year



g. SO_2 concentration, winter half-year

Fig. 10a-g (continued)

Table 9a Air quality difference between Saturday and weekday (Saturday – weekday),%

Automatic station	***Difference of daily average***				
pollutant	CO	NO_x	O_3	SO_2	dust
year	-12.5	-22.6	7.2	-12.6	-9.4
summer half-year	-9.9	-25.1	6.2	-19.6	-9.2
winter half-year	-13.5	-16.9	6.4	-3.4	-8.6

Table 9b Air quality difference between holiday and weekday (holiday – weekday),%

Automatic station	***Difference of daily average***				
pollutant	CO	NO_x	O_3	SO_2	dust
year	-17.1	-41.0	10.4	-25.7	-17.9
summer half-year	-14.2	-31.5	9.1	-15.6	-17.0
winter half-year	-21.8	-51.8	12.9	-36.6	-19.6

Table 9c Air quality difference between holiday+Saturday and weekday
[(holiday+Saturday) – weekday)],%

Automatic station	***Difference of daily average***				
pollutant	CO	NO_x	O_3	SO_2	dust
year	-15.0	-32.6	8.9	-19.8	-14.1
summer half-year	-12.1	-28.5	7.8	-17.5	-13.3
winter half-year	-18.2	-36.3	10.0	-22.2	-14.9

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INFLUENCE OF WEATHER - AS A CHANGING PART OF LANDSCAPE ELEMENTS - ON THE TOURISTICAL POTENTIALS OF THE KÁLI BASIN

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Összefoglalás - A dolgozatban összefüggést keresünk a Káli-medencébe látogató turisták száma és a napfénytartam között. A kutatás során arra a kérdésre keressük a választ, hogy a napfénytartam - mint változó tájelem - milyen irányban, és milyen mértékben befolyásolja a terület turisztikai vonzerejét, látogatottságát. Az 1999 nyarán végzett méréseink feldolgozása során június 25. és augusztus 20. között erős negatív korrelációt kaptunk eredményül, amely arra utal, hogy a fenti időszakban a medencét zömmel a Balaton partja mentén szabadságukat töltő üdülővendégek keresik fel. Ez az összefüggés a június 25. és augusztus 20. közötti hétköznapokra, és hétvégékre is érvényes. Ebben az időszakban tehát a borultabb, direkt napfénytartamban szegényebb időjárás emeli a terület turisztikai vonzerejét, mivel nem kedvez a strandolásra. Az augusztus 21. és szeptember 1. közötti időtartam alatt az előző időszakkal ellentétben pozitív korrelációs együtthatót kaptuk, amely jól mutatja, hogy a szezonális fürdőturizmus lezárultával a napfényben gazdagabb napokon magasabb volt a turisták száma, mivel ekkor már zömmel a környék nagyvárosaiból, valamint a fővárosból érkező kirándulók keresték fel a medencét. Ebben az időszakban a napfénytartam növekedése erősítette a Káli-medence turisztikai potenciálját. A Káli-medencében a napfénytartam alapján kimutattuk, hogy a medence a balatoni üdülőövezet vonzáskörzetéhez tartozik, turizmusának időbeni alakulása a nyári szezon idején partmentén üdülők migrációjától jelentős mértékben függ.

Summary - The aim of this study is to find out the connection between the amount of sunshine hours, as changing part of landscape elements, and the touristical attractiveness and the popularity of visitors in the Káli Basin in Hungary. The data have been collected between 25 June and 13 September 1999. The analysis of the data shows that in the period from 25 June to 20 August, strong, negative correlation exists between the above mentioned two variables; and the basin is visited by those tourists, who spend their holiday in the resorts at Lake Balaton. In the studied period the touristical frequentation of the area grew on cloudy days - when the amount of direct solar radiation is decreased - , probably because this weather is not favourable for bathing. Later, between 21 August and 13 September a positive correlation was found, which presents quite well that after the end of the bathing season tourists preferred to visit this area in days characterised by sunshine, and they mostly came from the neighbouring towns and from the capital. In this period the increasing amount of sunshine hours intensified the touristical potential of the Káli Basin. The above mentioned facts suggest, that the Káli Basin belongs to the touristical attraction zone of Lake Balaton and the number of visitors in the summer season depends on the migration of visitors of Lake Balaton.

Key words: recreation, sunshine duration, touristical potential, evaluation of landscape, weather conditions

INTRODUCTION

Significant question of the climate and weather related studies is to find out which climate elements influence the recreation and in what extent (*Perry*, 1997). *Smith* (1993) divides the tourism into two main groups: weather-sensitive and climate-determinated types. While in the first case the climate is not the most important influential factor, the latter includes the mass tourism along the shorelines of seas and lakes. *De Freitas* (1990) studies the effect of climate elements (UV-radiation, solar radiation, temperature, wind speed) on the comfort sensation of tourists in seaside holiday resorts, using questioners and statistical data analysis. Several authors study the relationship between the climatic elements and the number of visitors. Most of the studies (e.g. *Brotherton et al.*, 1980) analyse the statistical relationship between the number of visitors and the deviation of mean daily temperature from the mean monthly temperature; or they compare (*Muir et al.*, 1974) the amount of solar radiation with the popularity. These afore-mentioned studies resulted positive (0.60) correlation, but it is not surprising, if we consider that they made their investigation in the cloudy Great Britain.

Part of the Káli Basin, which belongs to the Balaton Recreational Area, has several touristical attractions, most of them are natural values (*Fig. 1*).

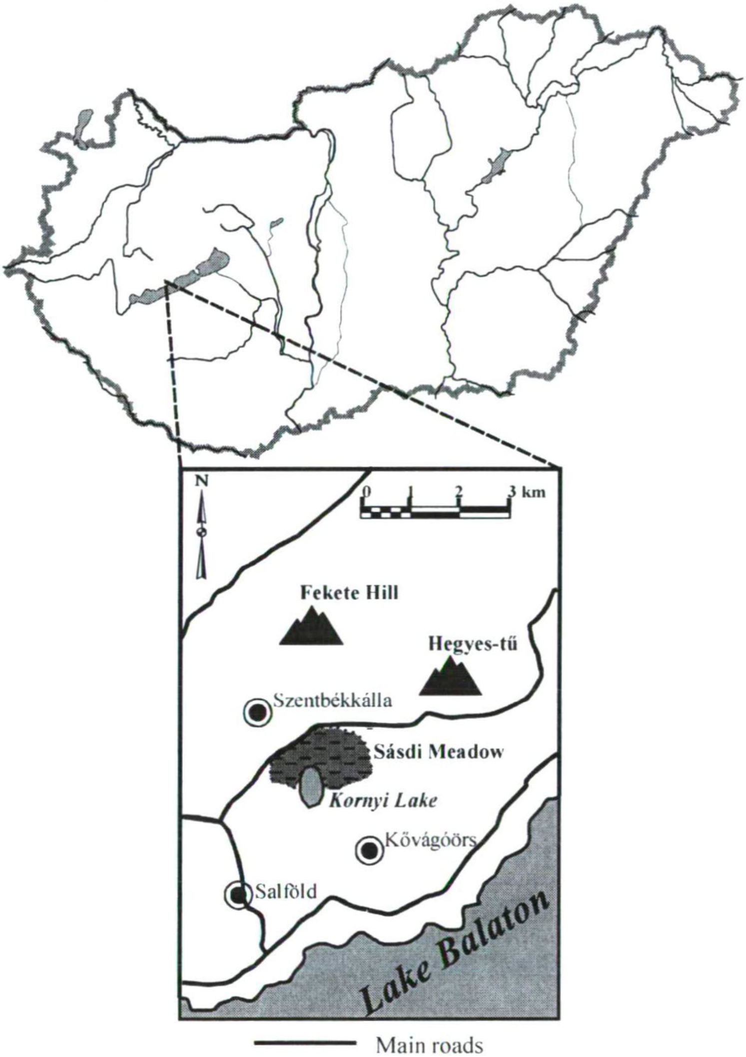

Fig. 1 Location of the Káli Basin in Hungary, touristical spectaculars and the sampling sites

The most well-known natural wonders are the block fields in the vicinity of Salföld, Kővágóörs and Szentbékkálla. The abandoned quarry of Hegyes-tű (a peak) represents an important geological value; moreover there is an open-air geological museum and an excellent vista point as well. The wetland habitats in the centre of the basin carries great botanical values, especially the Sásdi Meadow with several botanical unique species, and the lakes of the Fekete Hill (i.e. Kálomis Lake) or the greatest lake of the basin, the Kornyi Lake, are also valuable. The touristical potential of the area is raised by its richness in monuments and historic buildings. These unique landscape values appears as objective fundamentals, but the touristical attractiveness is influenced by the climatic elements as well.

THE AIMS OF THE STUDY

In this paper we draw a relationship between the number of visitors in the Káli Basin and the sunshine duration which is one of the most important weather elements. We would like to find out, whether the sunshine duration influences the touristical attractiveness, popularity of the area in the summer and in the autumn seasons; and if so, how and in what extent.

The aim of the present investigation is to answer the following questions by comparing the solar radiation with the number of visitors:

- Is there a statistical correlation between the number of visitors on the vista point of Hegyes-tű and the solar radiation measured in the basin (Salföld) (*Fig.1*)?
- Is this correlation valid for the whole studied period?
- What will be the sign and degree of this correlation, if we divide the studied period into summer season and autumn season?
- What will be the sign and degree of this correlation, if we analyse the weekdays separately from holidays and weekends?

The answers will help to draw a conclusion, whether the tourism in the Káli Basin depends on the tourism of the Balaton, if so it is important to study that when and how it depends on. Thus, we would like to know that the touristical attractiveness is strengthened or weakened by the increasing amount of solar radiation of a given period.

METHODS

The amount of sunshine duration was measured by Campbell-Stokes type of sunshine duration recorder in the neighbourhood of Salföld, between 25 June and 13 September 1999. We have summarised the direct solar radiation data for every 5 minutes. The amount of the astronomically possible sunshine duration is less by 185 minutes in 13 September than in 25 June; therefore, we have expressed the amount of real sunshine in percentage of astronomically possible sunshine by days.

The number of visitors was registered at Hegyes-tű, in its open-air geological museum. They must pay an entrance-fee, therefore we have exact data about their number.

We have taken out of the analysis the data of 11 August, because on this day, visitors came to this excellent vista point to see the total sun eclipse, and their number was far the greatest, approximately 1000.

RESULTS

As the first step of the investigation, we studied the statistical correlation between the real sunshine hours and the number of visitors during the whole study period (from 25 June to 13 September 1999). The correlation of 81 days' data resulted a –0.10 correlation coefficient. At this case number the correlation coefficient should reach ± 0.28 (*Péczely*, 1979) for 99% probability, but in our case the resulted coefficient is not high enough, therefore we concluded that in the studied period there is no correlation at 1% significance level between the degree of cloudiness (i.e. amount of sunshine hours) and the number of visitors.

The next step was to divide the studied period into two intervals. The line between them was 20 August, because in most cases, people's holiday will end at this time, as well as the bathing season of the Balaton Recreational Area. Fifty-seven days belong to the first interval (from 25 June to 20 August) with a –0.50 correlation coefficient; the second one includes 24 days (from 21 August to 13 September) with a +0.50 correlation coefficient *(Fig. 2a-b)*.

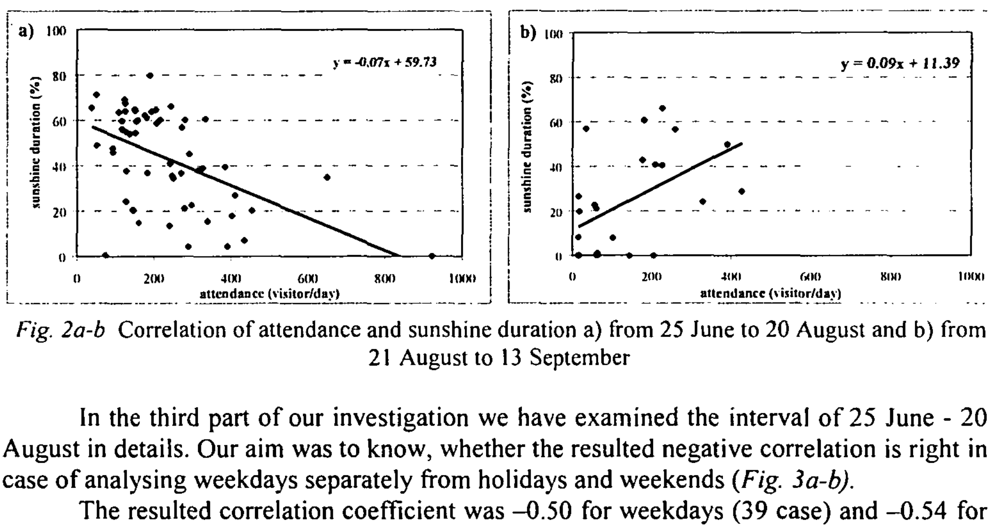

Fig. 2a-b Correlation of attendance and sunshine duration a) from 25 June to 20 August and b) from 21 August to 13 September

In the third part of our investigation we have examined the interval of 25 June - 20 August in details. Our aim was to know, whether the resulted negative correlation is right in case of analysing weekdays separately from holidays and weekends (*Fig. 3a-b)*.

The resulted correlation coefficient was –0.50 for weekdays (39 case) and –0.54 for the weekends (19 days). The first correlation can be considered as a real one with 99% probability as far the correlation coefficient for the 39 cases should be ±0.40. The second correlation can be considered as a real one with 95% probability because the correlation coefficient for the 19 cases should be ±0.45 (*Péczely*, 1979). Therefore, both for weekdays and for weekends we have received a statistical correlation, referring to the fact that each day of the weeks of this period the holidaymakers from the Balaton visit the basin.

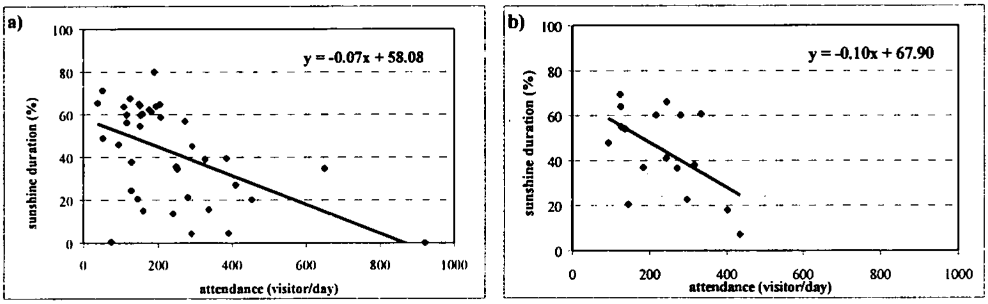

Fig. 3a-b Correlation of attendance and sunshine duration from 25 June to 20 August a) on weekdays and b) on weekends

CONCLUSIONS

Based on our analysis, it can be concluded that during the whole studied period (from 25 June to 13 September 1999) there is no real statistical correlation between the daily amount of sunshine hours and the daily number of visitors within the territory of the Káli Basin.

In the period of 25 June - 20 August there is a strong negative correlation, so the most probably visitors are the holidaymakers from the resorts at the Balaton. This relationship is valid for both weekdays and weekends. Thus, the cloudiness (e.g. the decrease of sunshine duration) increases the touristical attractiveness of the basin. In the interval of 21 August - 13 September the positive correlation suggests that in this period, visitors preferred sunny weather for travelling, and they came mostly from the neighbouring towns. In this period the sunshine supported the touristical potential of the Káli Basin.

Studying the amount of sunshine hours, we found that the basin belongs to the attraction of the Balaton Recreational Area. The temporal pattern of its tourism mostly depends on the migration of holidaymakers of Lake Balaton during the summer season.

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EXISTENCE, SURVIVAL AND RECOGNITION OF ICY METEORITES ON ANTARCTICA WITH RESPECT TO PALAEOTEMPERATURES

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Összefoglalás - A Naprendszer kémiai kondenzációs modellje, valamint a meteoritek megfigyelt jellemző tulajdonságai alapján jégmeteoritok létezését, földi becsapódás utáni túlélését és megtalálhatóságát vizsgáljuk. Összegyűjtjük azokat az okokat, melyek alapján jégmeteoritek létezése igen valószínű, majd megvizsgáljuk jégmeteoritok túlélésének lehetőségét az Antarktiszon, ahol egyáltalán föllelhetők lehetnek a földi környezetben. Az Antarktisz paleohőmérsékleteire következtetéseket vonhatunk le a túlélő jégmeteoritek feltételezhető ammóniatartalma alapján. Az Appendixben fölidézünk egy föltételezhetően jégmeteorit kapcsolatú hullásról készült jelentést 1875-ből.

Summary - On the basis of characteristics of some meteorites (cold meteorites after falling, fragility), of the chemical condensation model of the Solar System, and also according to the main components of comets icy meteorites can be suspected to exist. Firstly, the reasons are listed which make it plausible that icy meteorites can indeed exist. Secondly, we enumerate arguments for their preservation on Antarctica, where they might be collected. The survival of an ammonia-bearing icy meteorite implies temperature constraints for Antarctic palaeotemperatures. An Appendix recapitulate and comment the scientific report on a possible icy meteorite fall in 1875.

Key words: icy meteorites, Solar System mineral belts, cometary contamination, paleoclimate on Antarctica.

1. INTRODUCTION

In general meteorites give a distorted but still characteristic sampling of the Solar System. Theoretical papers on the formation of the primordial system suggests substantial gradients of chemical concentrations, along with the thermal and pressure gradients; moreover observations on fallen meteorites as well as on asteroid spectra corroborate this expectation. However one of the theoretical predictions still remains without (direct) observations. While in the theoretical scheme (contaminated) ices are structural components of minerals from Jupiter outwards *(Lewis and Barshay,* 1974; *Larimer,* 1967; *Grossman,* 1972), and indeed astronomy observes ices at Iovian and Saturnian moons, in Saturn's rings, at Pluto and maybe Chiron, we do not observe ices in oncoming meteorites.

Nevertheless, it is easy to see that everywhere on Earth, except Antarctic interiors and maybe northern Greenland, the chances are nil for survival of extraterrestrial ice for a substantial time. So here we discuss two observations maybe suggesting an ice coating during fall (*Török,* 1882), and a possibility of permanent survival of recognisable icy meteorites on Antarctica.

By investigating extraterrestrial ice, one would get deeper insight into the structure of the Solar System, and could once more check the theories of its formation. We guess that icy meteorites would be almost as frequent as stony ones; only they melt and vanish rapidly on the main part of the globe.

2. IMPLICATIONS FROM THE CONDENSATION MODEL FOR THE SOLAR SYSTEM

Different calculations on the chemical equilibrium for minerals, condensed from the primitive Solar Nebula with cosmic (solar) chemical abundances, were published in the late 60's and early 70's (*Larimer,* 1967; *Lewis and Barshay*, 1974; *Grossman*, 1972). The main conclusion of such models was that three distinct material belts can be distinguished in the condensing solar nebula: the metal, the silicate and the ice ones (*Fig. 1*).

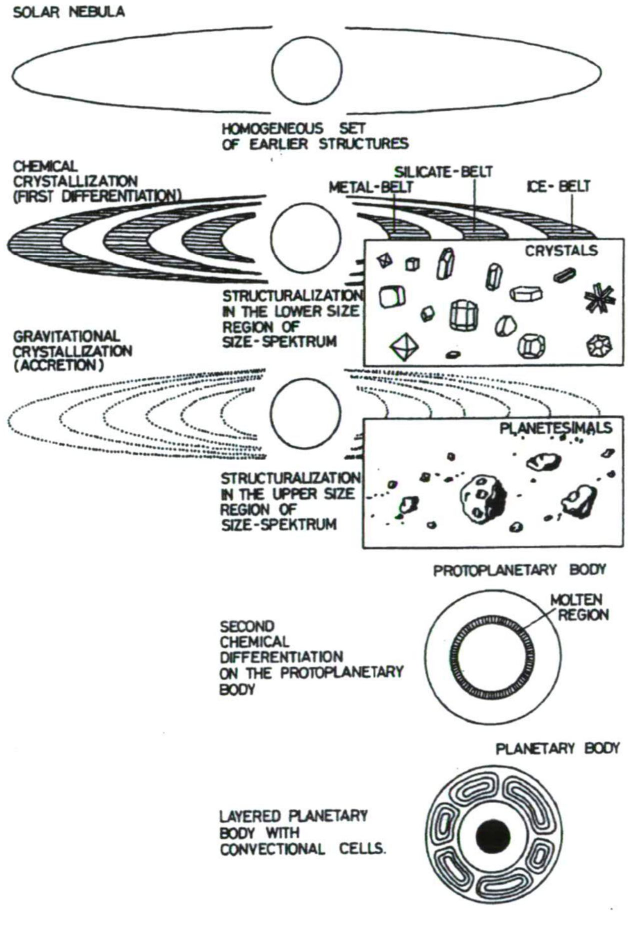

Fig. 1 Main steps of the evolutionary process of the Solar System from primordial solar nebula to global differentiation of planetary bodies. Central column: 3 stages of solar nebula. Right: events of planet formation.

For definiteness' sake we refer here to the work of *Lewis and Barshay* (1974). They calculated the sequence of precipitation of a gas nebula with solar elementary abundance when temperature decreases on to the Cameron adiabatic. In their summarizing map of the p-T diagram of solar gas, the phase boundaries of solid phases in equilibrium with solar p-T conditions had been deduced by the intersection of these boundaries and the Cameron adiabat. The map shows that the temperature inhomogeneity differentiates the nebula. The temperature depends both on solar distance and time. Temperature, decreasing with solar distance, forms mineral belts around the Sun. Slow changes in the local temperature result in a time dependent precipitation sequence in the belts.

The sequence of minerals, shown on *Fig. 2,* is the following:

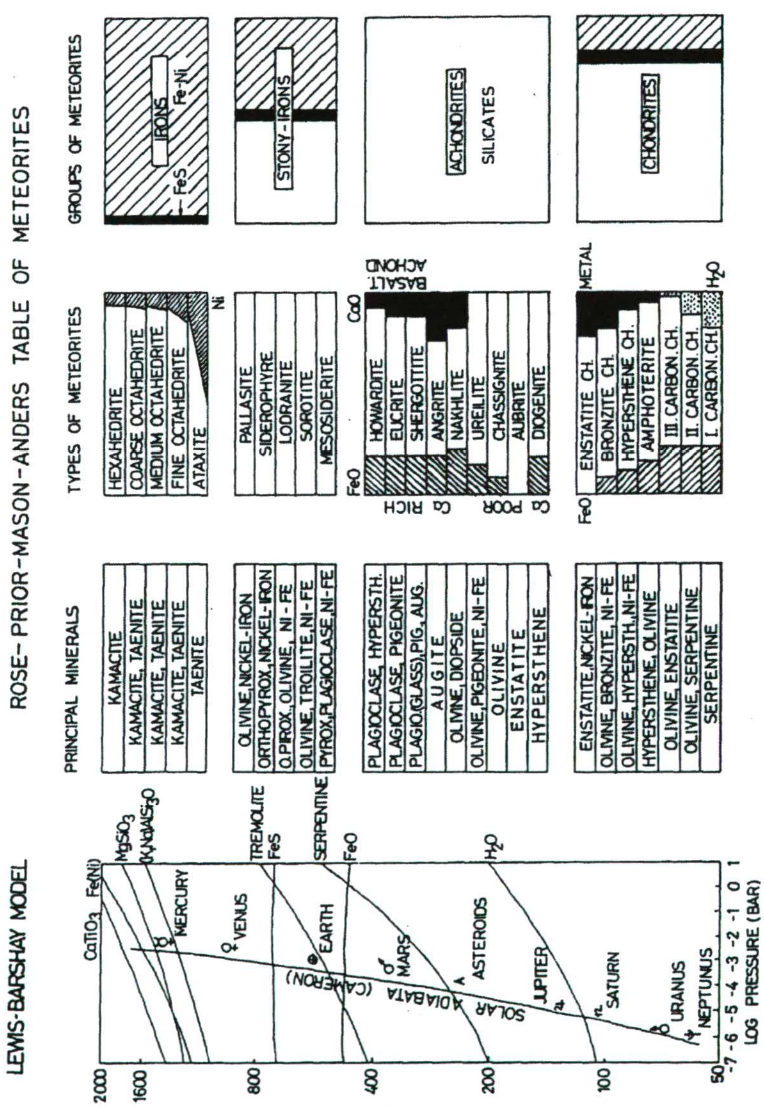

Fig. 2 Summary of the chemical crystallization in the Solar System according to *Lewis and Barshay* (1975) and of meteoritic counterparts of these mineral bands. (The Rose-Prior-Mason-Anders table from *Bérczi,* 1991).

Temperature	*Elements, reactions*	*Mineral*
1600 K	CaO, Al_2O_3, REE oxides	Oxides (e.g. perovskite)
1300 K	Fe, Ni alloy metals	Fe-Ni
1200 K	$MgO + SiO_2 \rightarrow MgSiO_3$	Enstatite (pyroxene)
1000 K	Alkal. oxid. + Al_2O_3 + SiO_2	Feldspar
1200-490 K	$Fe + O \rightarrow FeO$, $FeO + MgSiO_3$	Olivine
680 K	$H_2S + Fe \rightarrow FeS$	Troilite
550 K	Ca-minerals + H_2O	Tremolite
425 K	Olivine + H_2O	Serpentine
175 K	ice H_2O crystallizes	Water-ice
150 K	gas NH_3 + ice $H_2O \rightarrow NH_3.H_2O$	Ammonia-hidrate
120 K	gas CH_4 + ice $H_2O \rightarrow CH_4.7H_2O$	Methane-hidrate
65 K	CH_4, Ar crystallizes	Methane, Argone ices

According to the presence of H_2O the sequence can be divided into groups. The two main belts (those with and without ice) are "separated" by the troilite belt.

The corresponding solar distances need reconstruction for the proto-Sun. However, from planetary compositions one may get roughly the double of the present temperatures (*Lewis and Barshay*, 1974). This means that the inner boundary of substantially hydrated minerals was cca. 1 AU and the innermost region for "pure" ice crystals was roughly 5 AU (Astronomical Unit).

Nevertheless, from the point of view of meteorite classification three main belts can be recognized: metal, stone (or silicate) and ice ones. Iron, stony-iron and stone meteorites are well-known, but, comparing the estimated mineralogy of these chemical models and the main types of meteorites, an important hiatus emerges. We summarize on *Fig. 2* the main meteorite types (*Anders,* 1964) and mineral belts in a form which clearly exhibit this hiatus. The correspondence between mineral belts of the condensing solar nebula and the main (and intermediate) meteorite types shows sharply that representatives of icy meteorites are missing.

Meteorites intermediate between the metallic and stone ones are well known. Of course, we should exclude pallasites and lodranites from this discussion, since they were, most probably, produced secondarily inside of planetesimals, asteroids etc.; however chondrites in themselves exhibit a wide range of metallic Fe content. Now, by analogy, one might look for icy-stone chondrites, and they indeed exist; carbonaceous chondrites contain volatile elements and structural water up to 15-20 weight % (*Yanai et al.*, 1995).

Therefore it seems that the belt scheme of the theory is qualitatively correct and may be relevant for meteorites too; simply icy meteorites have not been collected for some reason. And indeed on the majority of the terrestrial surface local conditions are against the survival of an icy meteorite. On the other hand, there are places on the globe, which might preserve some pieces of them: especially Antarctica. The Antarctic meteorite collecting projects, and especially the Japanese one (*Yanai and Kojima,* 1987; *Yanai et al.,* 1993), led to the recognition of new types; they may lead to the identification of this group too.

For some support we note that some descriptions of earlier meteorite falls may contain some important details referring somehow to the existence of volatile components, which later were not found at all. One such event happened in Hungary, when not only the intensity of the phenomenon suggests that there were missing masses, but the condition of the found pieces (having been cold) is also in accord with supposed volatile components of the falling body.

Observe that icy-stones ought to be discriminated from the mixtures of ices and stones. In the first case the ice (water) would not percolate, so for first glance the meteorite would seem a stone one, only very fragile. However the fine distinction may wait until good specimens are found.

3. METEORITES, FOUND IN COLD CONDITION JUST AFTER FALL

Accept, for a moment, an icy block with embedded stone fragments (just as in comets) to fall as a meteorite. That event would be more or less similar to the fall of a stone meteorite, except that

- the body can disintegrate into many pieces in the fall;
- ice fragments without stone core may vanish in mid-air, or on the ground, so less meteorites will be found than expected from the intensity of the shower ("missing mass");
- the stone cores will seem usual stone meteorites; but if the ice coating survived the fall then it is without surface melting;
- if, miraculously, the stones can be collected just after fall, then they are surprisingly cold.

Now one can see that indeed the reliable observation of an icy meteorite is difficult. Points 1 and 2 need observers reliable not to exaggerate, and without superstitious interpretations of shooting stars. Point 4 needs the fall to the immediate neighborhood of human habitat, together again with the reliability of the observers. This feature cannot be relied if the scientific investigation did not follow the fall in days. It is true that, Point 3 is a permanent feature, but stones without molten surface are rarely collected as meteorites. These factors in themselves may responsible for the lack of our knowledge about icy meteorites.

Still there are rare events which might have been falls of icy meteorites. In his work "A Magyar Birodalom meteoritjei" (The Meteorites of the Hungarian Realm), *Török* (1882) describes a meteorite fall, when the pieces of the meteorite were found in cold condition. This was the Zsadány Meteorite.

The fall happened on 31st March 1875, in the vicinity of the village of Zsadány, in Temes County, Hungary. (Zsadány, now it is called Jadani, belongs to Romania.) Between 3 and 4 p.m. after a great thunder from the clear sky a swarm of rather small pieces of meteorites fell to the fields and gardens of the village. (For the locality, see e.g. *Herner,* 1987.)

It was very remarkable that when the pieces of the meteorites were taken into hands, they were found very cold. The author remarks, that there was another case, when a meteorite brought the "coldness of outer space to the surface". This event was in India, at Dhurmsala (or Dharmsala, Punjab), on 14th July 1860. There was found six pieces of meteorites and those were so cold, that, as reported, "people could not hold them for longer time in their hands".

The pieces of the Zsadány Meteorite are rather small like nuts; 9 pieces were found, representing chondrites. 3 pieces can be found in the Mineralogical Collection of the Eötvös University, Budapest, under the catalogue numbers L 376, 377 and 378, with masses 14, 38 and 45 g, respectively. They are denoted in the catalogue as "spherical chondrites". It is worthwhile to note that the Zsadány event was well documented and investigated. The Lord Lieutenant of Temes County immediately reported the event to a scientific journal, enclosing two fragments. The meteorites fell in early afternoon to gardens, ploughfields and meadows, many eyewitnesses were present at this event. The Hungarian Academy of Sciences sent investigators to the site in 15 days, they questioned many eyewitnesses, and organized a systematic search with 30 persons after fragments in the area whither witnesses had seen several "stones" to fall, but only one tiny fragment was found. The eyewitnesses did not report light phenomena, and did report delayed falls in a period of 30 seconds. The results of the investigation were published immediately (*Krenner*, 1875). In the Appendix we recapitulate the relevant part of the report, never published in any other language than Hungarian.

We think that the data at least suggest that the Zsadány meteorites originated from an icy body with chondritic stony fragments embedded. (The Dharmsala event is impossible to reconstruct because local people collected the pieces and details are not known.) The probable story is that the parent body fragmented during the fall, most fragments were ices and partly evaporated in fall, partly liquefied before finding them, and the stony fragments were preserved from heating by their icy covers. We performed a preliminary visual investigation on one of the Zsadány meteorites; the results are not enough for publication but will be mentioned at the end of the Appendix.

We note at this point that the Tunguz event had a material source, of which only traces remained, but most of it seems to have evaporated.

4. ON THE POSSIBILITIES OF FALLING ICES AND THEIR OBSERVATION

In this Chapter we discuss the possibility of such events. As for probability, only very rough semiquantitative estimations would be possible at the present state of art. We can say that this probability is a product of factors describing the abundance and different survival chances of icy blocks. These points are treated separately below.

1) Origin

Ice is a substantial component in the outer Solar System (theoretical suggestions were given in Chap. 2.) Now, let us see the observational data. (*Francis*, 1981; *Encrenaz et al.*, 1990). Theory predicts that ices will be more and more dominant in the mineralogy of the bodies going outwards from the Sun. Indeed, some Iovian and many Saturnian satellites have icy surfaces. The same is true for satellites of Uranus but the composition seems to change: the Iovian moon, Europa, has mainly water ice, the Saturnian ones may contain ammonia too, but high ammonia content in the mixture is not expected, since for cosmic abundance N is no more than 1/8 of O (*Novotny*, 1973); and on those of Uranus observations suggest mixtures of water, ammonia and methane. Methane ice is abundant in the Pluto-Charon system, and sometimes the outer asteroid (?) Chiron is believed to represent a family of outer primary small icy bodies (to which Pluto also may belong). If so, then these objects may correspond to the ice belt of the scheme. From these planetary and satellite surfaces impacts may throw ices to interplanetary orbits in the same way as they throw fragments of inner bodies resulting in metallic and stony meteorites. Of course, escape velocities are needed and this may be a problem for the Iovian and Saturnian satellites.

Obvious sources of meteorites are disintegrating comets; some observations suggest such origin for some "meteor swarms". Now, comet cores are believed to be stones cemented by ices.

So, as for origin, ices approaching the orbit of Earth may be as frequent as stones, and they may contain water, ammonia and methane.

2) Survival on orbit

At r solar distance the equilibrium temperature of a grey body is

$$T_{eq} = (R_S/2r)^{1/2}\, T_S \tag{1}$$

where R_S is the solar radius and T_S is the solar surface temperature. Hence, at 1 AU one gets 276 K, mere 3 degrees above the freezing temperature of water ice at very low pressures. In addition, ices are not grey because of high albedoes in the visible range dominant in solar irradiation, but definitely lower ones in the near infrared on which they radiate back. Therefore, a clean ice block could survive long on Earth's orbit, and indeed, comets survive the crossing although they lose some part of their ices.

Still some caution is needed. First, there is evaporation even under the freezing point; for this the same can be said as for the comets. Second, the surface may collect dust, which would increase the temperature to T_{eq}. However, then fast evaporation starts carrying away the dust particles, too. So ices may survive several crossings of Earth's orbit. More definite calculations are pointless now, since the survival rate/revolution depends more on the perihelion distance (which may be various) than on the details of the radiation balance at 1 AU.

3) Survival during fall

In the fall, the evolution of a meteoritic body is governed by 3 coupled differential equations whose approximate form for a sphere of radius R and mass density μ is as follows:

$$(4\pi/3)\mu R^3(dv/dt) = F_{drag} - (4\pi/3).\mu R^3 g \tag{2}$$

$$F_{drag} = F_{drag}(R,v,z) \tag{3}$$

$$(d(4\pi\mu R^3/3)/dt)cDT = \mathrm{Wheat} = F_{drag}.v \tag{4}$$

$$dz/dt = -v.\cos\Theta \tag{5}$$

where F_{drag} is the drag force on the falling body, v is the velocity, z is the height, Θ is the angle to vertical, c is the specific heat, and DT is the difference of the evaporation temperature and the original one. Depending on the original dustiness of the surface, the latter is 200-270 K, so DT is comparable to 100 K. In addition, the latent heat of evaporation should be taken into account, which is again substantial. As for the drag force, the simplest approximation, (which must be corrected at high velocities), is the Stokes law

$$F_{drag} = 6\pi\Gamma(z)R(t)v(t) \tag{6}$$

where Γ(z) is the viscosity of air, depending on T(z).

Now observing that for ice DT is roughly 1 order of magnitude smaller than for silicates but c half an order higher, and the evaporation heat is high. Therefore the total mass loss of ices and silicates during fall is roughly similar. If stones can reach the surface, ices can either.

4) Survival in the impact

This is a rather obscure point. If a substantial part of the original velocity is retained, then at the impact the ice block breaks and some part liquefies. However fragments may survive in frozen state. We think that extraterrestrial ices could be recognized from composition; see later.

5) Survival on the surface

Now let us assume that an icy block survived the descent and landed in the interior of Antarctica. Then the next question is if it has a chance to survive until discovery. The survival is only necessary, not sufficient, condition for later observation, since a lot of interactions can be imagined between the icy meteorite and the ice and snow. (The meteorite can be buried by snow as well as stony meteorites can; it may be frozen to the surface, etc.) These interactions may be complicated. However the survival itself, i.e. the resistance to melting, depends on fundamental physical, chemical and meteorological facts.

First we list the melting points of possible icy meteorites, all for normal 1 atm pressure.

The melting point of the icy material strongly depends on chemical composition, which is expected to widely vary in the Solar System. So the survival chances depend on the place of origin. A complete analysis is not possible in the present status of our knowledge about the outer Solar System, but some possibilities can be discussed, according to the theoretical scheme and observational data mentioned in earlier Chapters.

Most obvious sources of icy meteorites are the cores of comets. There the possible constituents, according to cometary spectroscopy, are water ice, carbon dioxide, ammonia, methane and cianides, with their mixtures, clathrates, etc. The best known such body is Halley's Comet, where the ice seems to be dominated by H_2O with some percents of CO and CO_2 and 0.1% of cyanides. Cometary ices may carry stony fragments with them.

As for planetary bodies, we are going outwards. The first great extraterrestrial store of ices is Mars. Note that the stony shergottites sometimes are believed of Martian origin (*McSween and Stolper*, 1980; *McSween et al.*, 1979), either as direct products of a meteoritic impact on Mars, or helped to escape by water vapors deliberated from permafrost by the impact. In any case, if shergottites may come from Mars, ices may too; these ices would be contaminated by carbon dioxide and may contain stones. We note that the polar caps are believed to have water and carbon dioxide ices in comparable amounts, and the Viking probes observed H_2O-CO_2 clathrate rime.

As for the asteroid belt, no icy asteroid has been seen, so this source will not be discussed.

Some moons of Jupiter do have icy covers, most abundantly Europa. Of course, the escape from the Jovian system is difficult. For any case, the ice of Europa seems water-dominated.

Some moons of Saturn are icy, as well as the rings. Again, escape seems difficult from the system.

Going farther, one expects more and more ammonia and methane ices (*Bérczi and Lukács,* 1995). Oxigen is so abundant (*Novotny,* 1973) that water ice is probably not suppressed at any distance; but methane ice can be quite abundant at the outer fringes of the System. Such mixtures are seen on moons of Uranus on the surfaces of the Pluto-Charon double system. Also, the suspected asteroids outside Saturn (see e.g. Chiron) may be sources of mixture ices, and thence escape would be easy in an impact.

Now, dominantly methane ices cannot survive even in the neighborhood of the orbit of Earth, and dominantly ammonia ices cannot survive even on Antarctica; but we do not expect such ones anyway. So henceforth we concentrate on mixtures in which water ice is dominant. Water may form a variety of clathrates with the other molecules mentioned here; for that possibility the reader may consult the detailed chemical literature (*Berecz and Balla-Achs,* 1980). We deal here mainly with solutions or mixtures. For definiteness' sake we consider an environment permanently below -10°C.

Water can solve a substantial amount of CO_2, still with melting point above -10°C.

Cyanides mean a variety of molecules. We discuss here the two simplest: dicyanide C_2N_2 and hydrogencyanide HCN.

Dicyanide freezes at -34.4°C. It can fairly be solved in water (some 1 weight% at room temperature; henceforth% means always weight%), and, due to the Raoult Law, this quantity would decrease the freezing point of the ice by less than 1°C. Therefore, dicyane-contaminated water ice can survive for long time.

Hydrogen-cyanide can be solved in water in any quantity, and, when pure, its freezing point is -15°C. So ices, even strongly contaminated by HCN, can survive for long time.

Methane freezes much below the Antarctic temperatures. Since water can solve only small quantities (0.001-0.01% in the relevant temperature ranges), only very lightly methane-contaminated ices can be formed; however these can survive indeterminably.

Finally we arrive at ammonia, and here we go into more details. Since ammonia freezes at -78°C, ammonia-dominated ices cannot survive. However, according to the Raoult Law 1% ammonia content decreases the freezing point to -1.1°C, therefore water ice can survive with several% of ammonia contamination for a long time. As for solubility, 0°C water-ammonia mixtures can go up to 47% NH_3 content. For more detailed phase diagrams see e.g. *Kargel* (1992).

Now, the original percents could be anything according to the parent body, so the subsequent fate on the Antarctic ice can be diverse. For more detailed statements the H_2O-NH_3 phase diagram would be needed, but this diagram is very complicated (note e.g. the wide variety of low temperature water ices) and belongs to low temperature chemistry. However, for our present purposes we do not have to go below moderately cold temperatures, and therefore a simple approximate scheme will suffice.

According to the Raoult Law, in dilute aquatic solutions 1% ammonia decreases the freezing point by 1.09°C. For liquid ammonia, solving water ice experiments are harder, but the van t'Hoff Law gives 0.53°C decrease to 1% water ice. So at both extremal compositions the mixtures freeze well below the simple linear interpolation of the freezing points of the pure liquids, as shown by *Fig. 3.* This is similar to the state diagrams of metals with eutectic alloys. We are not interested in the details around the crossing point of the Raoult lines because that state belongs to 80.5% NH_3 content and -88°C temperature, out of the scope of our discussion; however, the simplified scheme makes the verbal argumentation easy.

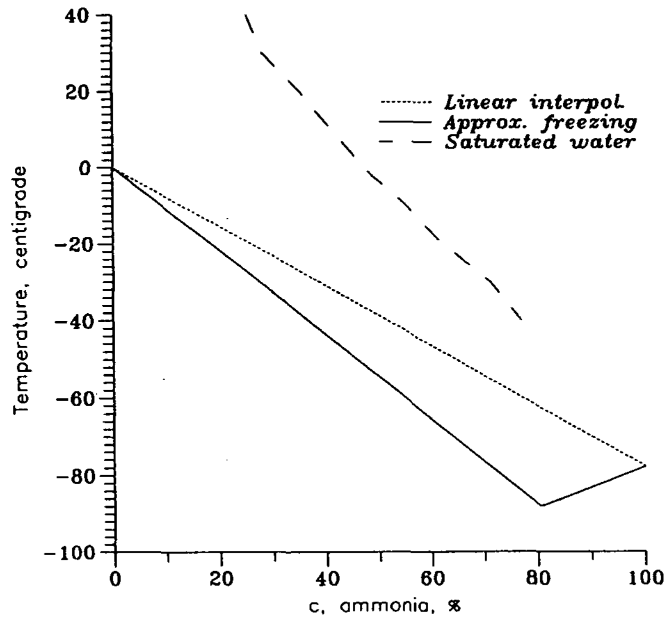

Fig. 3 Phase diagram of ice and ammonium. Melting points in the water-ammonia mixtures are somewhat simplified. Initial slopes are determined by the universal Raoult Law and suggest eutectic behaviour. For minor comlications see *Kargel* (1992).

The dashed line is the solubility curve (for NH_3 solved in H_2O; we are not interested here in the opposite case). For low temperatures we extrapolated the observations.

As an example consider the fate of an ice block with 20% ammonia content from winter to summer. The freezing point is some -22°C. In the winter the block remains frozen. However in some spring noon the block starts to melt. Then, as the diagram suggests, an ammonia-dominated component separates as liquid. Now, the temperature is above the boiling point of pure NH_3, and above that of the "eutectic". Consequently, the separated liquid fastly evaporates. The result is a continuous depletion of the ice block in NH_3 at least on the surface. The process stops at the NH_3 content to which the freezing point is the summer maximum temperature. This is roughly 9% NH_3 at -10°C.

Now let us look for the possibilities of environments permanently below -10°C; as we have seen, then even contaminated ices can survive. However, note that the main part of Antarctica lacks regular meteorological observations. Majority of stations are located near the shore with a mild climate, which is not hopeful for longer survival of icy meteorites. In the interior the conditions are better, but thence it is harder to collect meteorites, and the meteorology is less known.

In the Antarctic interior the meteorite is under cca. 1 atm pressure, and the summer mean temperature is well below 0°C. For the interior of the Dronning Maud Land, about 72° latitude, the January mean temperature seems to be -16 – -20°C, while the July value somewhere around -40°C. From the observations of some regular stations the daily variations seem to be in the order of 10°C. So we would expect -10°C as upper boundary of "normal" peak temperatures. Still, this value is doubtful: on some favored meteorite sites of the Dronning Maud Land Japanese expeditions observed traces of previous melting processes (*Yanai et al.*, 1993); nevertheless, not above 2000 m elevation. This suggests that there are occasional events of temperature increases. The neighborhood of the McMurdo station, where also some collection happened, is more southward, but at the station, on the shore, summer climate is mild. Maybe among all the sites where meteorite collection happened up to now, some in the Trans-Antarctic Mountains would be optimal for survival of contaminated ices.

Anyway, there are sites, not too remote for work, where moderately contaminated water ice remains frozen permanently in the present status of Antarctica. However, meteoritic falls are rare events, and the collected meteorites have been accumulated for a long period. So palaeotemperatures should be briefly discussed, which will be done in the next Chapter.

6) Chances of recognition

For pure water ice the meteorite cannot be identified. Stones covered by ices (as the Zsadány and Dharmsala meteorites) can be identified after collecting, but it is hard to find among similar terrestrial ice. A possibility of identifying NH_3-containing ices on site by reflection spectrum is under investigation by the authors. There exists a proposition for an electric (induction) measurement on ice fields (*Földi et al.*, 1995) to detect the presence of contaminating matter in water ice. However, we must admit that the outward similarity of the ice meteorite and the icy environment is a serious problem reducing the probability of collecting such meteorites.

However, assume that an ice block has been collected. Now, how can it be identified it as an icy meteorite?

A water ice block without stone core is of course hardly distinguishable from native Antarctic ice. Extraterrestrial origin, if suspected, can be checked by analysis of trace elements.

If it contains a stony core, then it can not be originated at the Antarctic interior, where native stone is absent. (True, some 10 of the more than 3000 analyzed Antarctic meteorites are (pre)classified as "terrestrial"; none has yet a bulk composition analysis (*Yanai et al.*, 1995). Their presence is unexplained up to now.) A possibility is some Antarctic ice coating of a stony meteorite. We cannot calculate the chances of such a process; however the fine chemical analysis of the water ice may help.

Contaminated ices need some attention according to the contaminant, as follows below.

Carbon dioxide of course contaminates all terrestrial waters, but its atmospheric concentration is 0.03%; therefore, only moderate CO_2 content is expected if the origin was terrestrial.

Free dicyan and hydrogencyanide are absent in natural terrestrial environment.

Methane can contaminate water in swamps, but the Antarctic interior lacks swamps in the last 5 million years. Hydrocarbon fuels may contain methane in small amounts, but previous spilling of oil-based fuels can be detected.

Ammonia is not totally absent in natural environments. E.g. some bacteria produce it from decaying organic matter. This situation is absent, however, in the Antarctic interior. The urine of lower animals contain a substantial quantity of ammonia; but higher animals convert it mainly to carbamide in urine, and in the Antarctic interior lower animals are absent. True, mammal urine does contain some ammonia, but never without dominating carbamide. So if there was ammonia content without carbamide, then the ice cannot originate in the Antarctic interior.

5. ON ANTARCTIC PALAEOTEMPERATURES

Antarctica is in her southern polar position since Mesozoic (*Plumer and McGeary,* 1991). However after the mid-Permian glaciation (*Koppány,* 1996a; *Koppány,* 1996b; *Bérczi and Lukács,* 1997) Antarctica was free of permanent ice until mid-Pliocene, cca. 5.5 Ma ago. Antarctic icefields started with the Plio-Pleistocene glaciation. This period we survey retroactively.

We are in the Flandria interglacial after the Würm glacial. On large scale, the present temperatures are the highest at least after the start of Würm II, some 65,000 years ago. True, in Europe a temperature peak existed between 5500 and 3000 BC (*Clark,* 1969), but even then the temperature was higher in Western Europe by a mere 2.5°C.

Before Würm II we are out of the C14 horizon, so the chronology is obscure. Ice samples from NW Greenland (*Koppány,* 1996b) suggest, however, quite mild climate, comparable to present, between Würm I and II. Maybe so far the Würm was the coldest glacial period, so the Riss/Würm interglacial may well have been warmer than the present climate (*Zeuner,* 1959). So the present Antarctic temperatures are not representative before 65,000 BC. Note that the last melting obliterate all earlier ice meteorites (for irreversible processes see e.g. *Lukács*, 1992), and that time melting was possible except the very deep interior. Also, ice blocks are not supposed to have retained their identities in icy environment during long times and meteorological oscillations. So the beginning of the Würm is practically the absolute time horizon for the icy meteorites.

6. CONCLUSIONS

The aim of this paper is to call the attention to search for icy meteorites. By definition, an icy meteorite is a block of extraterrestrial ice in collision course with Earth which survives until the surface. We enumerated arguments:

- Such blocks on collision course may be frequent. Indeed, there are ices in the outer solar system (it is observed on moons and in comets); and they may survive some time even at 1 AU.
- During atmosphere crossing their relative mass loss is greater than that of stones but still comparable. So reasonable blocks can survive the deceleration.
- In the Antarctic interior the icy meteorites may remain frozen for a long time.
- A recovered piece can be identified by e.g. contaminants lacked in the Antarctic environment.

We cannot reliably estimate the finding probabilities since ice on ice is not too conspicuous, and also interactions may happen between terrestrial ice, snow as well as rime and the ice meteorite. However, until this factor undergoes detailed analysis, it is useful to keep in mind the suggested meteoritic class.

As for possible earlier observations, we listed two last century meteorite falls, at Zsadány and Dharmsala, when the stones just after fall were cold as if an ice coating had preserved them from heating. In addition we mention that an original ice coating would be a possible interpretation for some doubtful pieces of the Asuka-87 meteorite collection (from the Asuka Station vicinity, Antarctica). We close the conclusion with this suggestion.

A review article (*Yanai, et al.*, 1993) tells that the Asuka-87 meteorite collection "also includes doubtful pieces which appear black or dark brown in color, like deeply weathered H chondrites. However, there is no distinct fusion crust on their surfaces". Now, if we look through the description of the collecting process, it is said that in the beginning of 1988 more than 100 pieces were collected around Mt. Balchen (Antarctica) "with or without fusion crust". Now, according to the map of the description, the Mt. Balchen area is between 1200 and 1800 m elevation, and the collecting party saw definite traces of melting in the area, mostly below 1500 m.

So assume that an ice block with embedded stones (just as in comets) landed in the Mt. Balchen area. Then the next melting process eliminated the ice cover and the stone remained, of course without fusion crust. If the meteorite came from a comet, then the stone is probably chondritic, just as found. A comparison of the doubtful Asuka-87 chondrites and the Zsadány fragments might be edifying.

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APPENDIX: THE CONTEMPORARY REPORT ON THE ZSADÁNY METEORITE FALL

Here we partially translate the scientific report on the Zsadány event immediately after the fall. The text is the paper of *Krenner* (1875), cited in the References. We, for the readers, give numbered notes in due course. Special attention will be given to the cultural background of eyewitnesses, because reports from stones falling from heavens may be colored by religion, superstition, etc. The time of the event was 7 years after introducing obligatory schooling in Hungary. This means that the middle age observers may or may not have got regular school education. Who had got, got it in a ground school of the local church because this was the general situation in last century Hungary in villages. Therefore the two main indicators of the cultural background of the Zsadány eyewitnesses are their religions (Temes County was a mosaic of religions) and profession. As for the latter one, the overwhelming majority of the village were farmers, not mentioned henceforth.

The investigation was made by the Royal Hungarian Society of Natural Sciences, not to be confused with the Hungarian Academy of Sciences. It was a scientific organization for propagating the science; the investigators were geologic experts. One of them, J. Krenner (1839-1920) was Professor of Mineralogy and Geology at the Pázmány University, Budapest, Chief Curator of the Mineral Collection of the National Museum, etc., Fellow of the Hungarian Academy of Sciences, discoverer of a string of minerals, as semseyite, kornelite, szomolnokite, andorite, lorandite, warthaite, fizelyte and schafarzikite. His name is commemorated by krennerite, a gold-telluride-sulfuride. So he was no doubt an expert mineralogist. The society had a monthly journal Természettudományi Közlöny, still in existence, in which they published the report.

The event happened on 31st March, 1875. The first report of the Lord Lieutenant of Temes County (*Fig. 4*), reached the Society on 14th, April, and the Society sent two investigators to the site on the same day. They arrived at Zsadány on 16th, April. Hence come the relevant parts of the original report (*Krenner*, 1875), orally given on 21st April in the Society. Some stylistic features of the text may be strange for the reader in English, but we wanted to give a translation as close to the original as possible.

"Zsadány[1] is a village on the Temesvár-Arad line[2]; near Merczifalva, east of it. The houses are built on clay soil, covering sand and pebbles. The houses form a rectangle, whose eastern side goes northwest. The meteorites fell into the easternmost houses and on the neighboring meadows and ploughlands.

In the house of N° 202[3], of Birejeszkú Paszku[4,5] the owners' wife Birejeszkú Maricza and mother-in-law with Plesuné[6] Djúla were working directly before the kitchen door, in the garden - this was between 3 and 4 o'clock p.m. - when sounded first a strong cannon boom, followed by musketry rattle and then by an uproar' as if the whole sky were to boil. The frightened women looked up to north, whence the terrible noise came, and Mariucza stepped aside. Just then a stone fell to the soil, just to the place where Mariucza had stood before, and went into the tough clay soil. They instantly took the black stone, which emanated a strong sulfuric stench[7]. The stone was quite cold[8], and Plesuné adds: icy cold. Later the sulfuric stench filled the whole garden, and became strong[9]. According to them the sky was quite clear with only a few small clouds. Fire phenomena were not observed on the sky. (The stone were sent to the Lord Lieutenant)

Márku Thoma, owner of the next house (N° 203) found later, on the 4th or 5th day after the fall, in his garden at the fence a stone which still had sulfuric odor[10]. The stone has been acquired by us. It fell 80 steps west of the previous one; half of it were in the soi.

Argyelánu Lázár, owner of house N° 128, was just working in his garden when became frightened by a very strong thunder above; this was followed by musketry roars, afterwards started a noise, which he can compare best to the noise of railway train[11]; then some steps from him a stone fell to the unhoed garden soil; a small dust cloud showed the place. Argyelánu Lázár instantly took the black stone of strong sulfuric odor; it was quite cold, which fact is corroborated by Szerbován Pável[12] as Szalka, and his wife Szanda, who had been just present and took also the stone into hands. This stone fell from the previous ones southwest, cca. 360 meters.

Spatario Constantin[13], owner of house N° 145 and his son Péter[14], both very open-minded and intelligent persons, tell that first happened a very strong cannon roar, then a musketry crack, followed in a little while by a special whistle; at the end of this a black stone fell into the garden on a chaff pile. Spatario Constantin and his son Péter instantly took the stone and it was quite cold as corroborated the housewife Spatario Florea[15], present at the fall. In cca. half a minute a second, much smaller stone fell; taken also instantly, but it was not warm either. In both cases, there was a strong sulfuric odor. The chaff was not burnt or parched. We asked him[16], if he had known, how long is half a minute, and he answered that he knew how long is a minute and between the two falls one could have counted roughly to 30[17]. The sky was clear, with rare white clouds, of which an oblong fleecy cloud was remarkable. But this cloud did not move and Spatario does not consider it to have been in connection with the meteorite fall. The fall happened between 3 and 4 o'clock[18], nearer to 4. The daughter of the owner, Zsófia[19], very intelligently mentioned that she had read a few week ago that sometimes stars fall to the earth, so when heard of the fall, she ran out asking her brother whither the star had fallen, and when he - with the stone in his hand - was just starting to show, fell the second piece, then Zsófia became so frightened that she ran into her room, was afraid to leave it during the afternoon, and being unable to dine anything.

The methodical investigation was made on 17th, Saturday, in a manner of a hunt, with some 30 men. We combed the vineyard, and also the northern and northeastern meadows and ploughlands. In spite of the statements of shepherds that they had heard there stones to fall, only a very small but complete meteorite was found by Gyuro Akim, on the meadow, 60 steps east from the Birejeszku house.

The thunder was heard in two neighboring villages, Szécsány and Orczyfalva[20], but not at Vinga[21]. Fire phenomena were not seen from these villages, as none of them from Zsadány.

In general, on the site, up to now[22], the fall of nine meteorites have been verified. From them 6 have gone into the property of the Roy. Hung. Society of Natural Sciences, and 3 pieces are in property of other certain persons.

The stones found up to now are not too large, hardly nut sized; their shapes are either rough spheroids, wedge or tablet forms. Their material is grey, trachyte-like, with many scales of blinking white (probably nickel-iron), with a black crust, somewhere rugged somewhere shiny[23]. The material is very similar to that of the Knyahinya meteorites[24]. The big thunder, terrifying not only humans but the animals as well, makes it very probable that bigger blocks fell also, but they, just as at Knyahinya, went into the soil, whence they will reappear during plowing or hoeing[25].

The definitely verified fact that the falling bodies, at least at touching the earth, were cold, it is very remarkable. Not stressing the expression "icy cold", it can be regarded as an established fact that these meteorites, when entered Zsadány and became terrestrial, were not warmer than the air temperature, then still rather low[26]. I do want to definitely stress this fact, in contrast to the cases when the higher temperature of the fallen meteorites were proven."

Here we stop with the text; the end contains mainly conclusions and acknowledgments, of which we only mention that of the helping activity of the village notary, Mosiescu Mózes[27], who seems to have escorted them in the village and who, by all probability, translated the Romanian answers[28].

We do not want to influence the readers. However, we state a few simple observations. The coldness of 4 meteorites is stated by 3 groups of eyewitnesses. It has nothing to do with Greek Orthodox popular religious ideas, it was reported by eyewitnesses of 3 different ethnic groups, and the reports were left without comment by the local clerk of different religious ideas. Therefore, it is either a fact, or a hoax in which the whole village participated, including the merchant, and, what is more, the notary. Now, the latter one was a member of the state administration, nominated by authorities well above village level, therefore he would have been afraid to misguide the emissaries of a nation-wide scientific society founded by a royal decree, who carried a recommendation letter from the Lord Lieutenant, and were accompanied by the local sheriff. In addition, the hoax would have been pointless. The village was not interested in tourism, and the population did not sell strange meteorites.

The observations clearly show missing mass, never found, and the lack of celestial fireworks suggests that the surface temperature during fall remained under 1000°C. The only fact contradicting the fall of ice-covered stones is the (partial) shiny crust of some meteorites, which may be fusion crust. So a reanalyzis of the event would be useful; however, note that a fusion crust is incompatible with the coldness, corroborated by 4 groups of observers.

To our knowledge, no results of new investigations about the Zsadány meteorites were published since 1882. We have performed a preliminary visual study of the piece L 377. It is an average-looking small meteorite. The crust is rather dark, nearly black, but only partial, covering cca. 2/3 of the surface. The stone is rather shapeless, and its surface is not smooth, unlikely to river pebbles. A number of protuberances appear on its surface.

Now, the crust is thin, and quite uniform in width. It closely follows all the protuberances of the surface, and no trace of flow of molten material can be seen. Therefore, it seems as if the surface had not been molten for longer times. Either we see the result of a very superficial melting, or that of oxidation in solid state, or that of some chemical processes in the prehistory. As for the areas, not covered by crust, they might have been formed by *fragmentation. However i) the meteorites were reported to have fallen to earth or to vegetation; ii) no irregularities* of the material are seen on the supposed breakup surfaces. So the fragmentation would remain without explanation.

No more can be told without a detailed reanalyzes which needs time. Note that even if the crust of the L 377 piece was fusion crust, the matter would not be settled. Namely, the contemporary report does not say that all the Zsadány meteorites were cold. It reports 9 pieces to be found and mentions 4 cold at fall: one in the Birejeszkú, one in the Argyelán, and two in the Spatario gardens. The report mentions 2 stones found days after in the soil: one in the Márku garden, and one found by Gyuro on the meadows. These two may or may not have been hot at the fall; and we do not know anything about the remaining 3 pieces. In addition, no document exists to state which one has been catalogued as L 377. So, even if 4 pieces had thick ice coatings, nothing can be told against such a scenario in which the coating of the future L 377 was thin, completely evaporating during fall and so leaving the stone exposed to friction heating for a short time.

We close by drawing attention to a point in the narration of Argyelánu. He saw the stone falling, and instantly took it. Now: it was cold, sulfurous in odor and black. Either the eyewitness remembered falsely, or the stone had got its black color earlier than the fall at cca. 3.30 p.m., on 31st March, 1875.

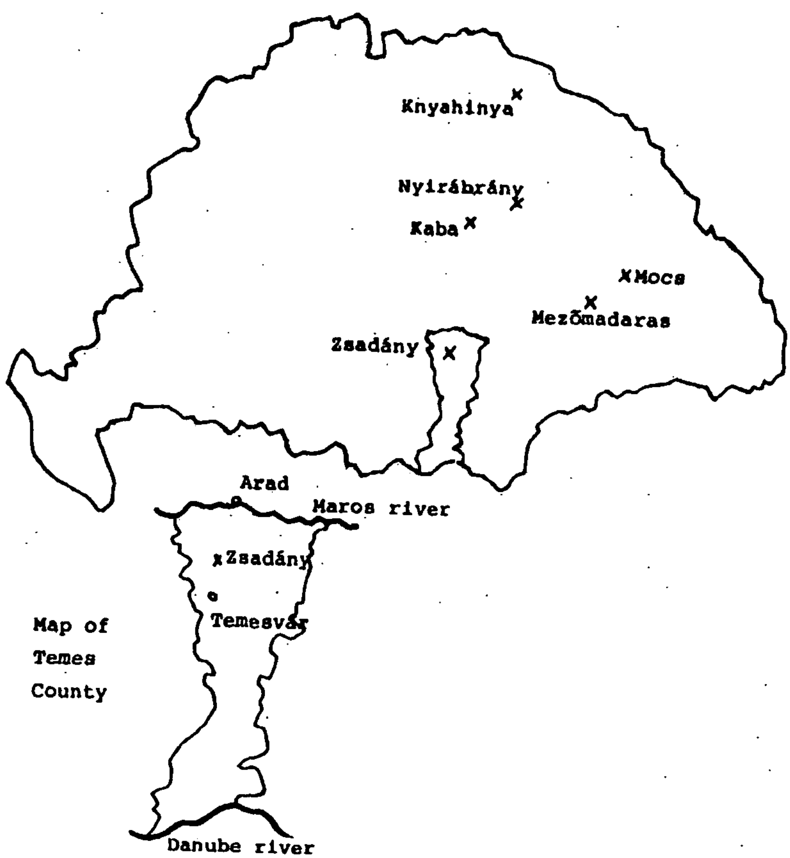

Fig. 4 Map of Hungary in 1875, when the Zsadány Meteorite fell. Five other famous meteorite sites are also marked, namely Knyahinya: the most massive, Nyírábrány: the most recent, Mócs: the most numerous, Mezőmadaras: the most cited and Kaba: the most organic.

NOTES TO THE APPENDIX

1. Present official name is Jadani, Romania. The pronunciation is the same, only the orthography has been Romanised.
2. Present official names Timisoara and Arad, Romania.
3. In small villages the houses were simply numbered for postal and administrative identification.
4. The names mentioned in the village are predominantly Romanian. In Temes County that meant to belong to the (Romanian) Greek Orthodox Church, whose administration shifted in those years from Cyrillic to Latin letters. So, for all probability the names are Hungarian transliterations of the original forms by Cyrillic letters. Also, we may expect that the overwhelming majority was educated in Greek Orthodox ground schools, if at all.
5. In Hungarian the first name is the family name. As an example, present Romanian texts would write the names of the Birejeszkú's as Pascu and Mariuta Bireiescu.
6. The suffix means that she was the wife of a Plesu.
7. This sulfuric stench will be repeated in the reports of eyewitnesses. It is not detailed. It may mean brimstone stench of something originated from Hell (but see the next Note), but the farmers may simply remember to sulfur vapors using for cleaning wine barrels.
8. So she could not believed it coming from Hell. Then the "sulfuric" stench was a real stench.
9. Sulfuric volatile deliberated? No explanation has been found up to now which is compatible with the coldness reported.
10. Again the "sulfuric" odor. Suggestions are welcome.
11. Railway lines reached the region some years before.
12. This name is clearly Serb. It means to be Greek Orthodox. Generally the Romanian and Serbian Greek Orthodox Churches were separated in Hungary, and Greek Orthodox churches used native languages in the rites even in the last century. We do not know, however, if there were a separate Serbian Church or school in Zsadány. The village was rather small.
13. This name is Greek. It is transliterated to Latin, not to Hungarian. According to the economic structure of the region he was probably the local merchant, and his family was literate. The Greek Greek Orthodox Church was quite separate from the Serbian and Romanian Greek Orthodox Churches.
14. The son's second name is written in Hungarian form.
15. Her second name is Romanian.
16. I.e. Spatario Constantin.
17. This definite statement suggests an extended source or a complicated fragmentation.
18. P.m.
19. The Hungarian form of the Greek name Sofia. The Hungarian forms of the children' names indicate that the interview with them happened in Hungarian. Greek and Armenian merchants of the region were multilingual.
20. The distance from Zsadány is 6 and 10 km, respectively.
21. 12 km from Zsadány. All 3 villages lie at north or northeast from Zsadány. The big city Temesvár with newspapers, journalists etc. was nearer than 20 km on the south, and nothing was reported.
22. I.e. 21st April, 1875.
23. This statement is not detailed any further. The shiny crust may or may not be fusion crust, but the rugged one may hardly be.
24. Ung county, now in Ukraine. The biggest observed meteorite event in Hungary, in 1866. Some 900 kg of fragments were found.
25. They did not reappear. No further meteorite was reported from the site, in spite of the attention. In the 1882 review article (*Török*, 1882) the new pieces should have been mentioned and they were not.
26. At the beginning of spring.
27. From the name probably of Israelite religion, which, according to this and to his office of a schooling, differs from that of the village people. Village notaries were nominated by higher authorities on the ground of being able to administrate, both on local language and on Hungarian, for communication with the county offices. Some moderate knowledge of law was needed too.

28. The linguistic problems involved are nontrivial. The text never mentions translation. However it must have happened. Temes County is an ethnic mosaic, and Zsadány was predominantly Romanian. The emissaries' passable Romanian is highly improbable. Romanian is Neo-Latin after a fashion (with more Latin words in Greek Catholic villages, due to the linguistic reforms of Bishop Samuel Micu-Klein of Balázsfalva), but cannot be understood via Latin, and contemporary popular Greek (Dimotiki) is very hardly understood via Classical Greek. But the male population of the village may have had a partial ability in Hungarian and German, from military service and because of the big city Temesvár at 20 km (where the dominant languages were German, Hungarian and Serbian). Probably the notary (whose family name indicates Romanian as first language) translated, but the subjects were possible to follow the translation partially. If they did not correct, the translation was considered exact.

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ANALYSIS OF PRECIPITATION IN BAKONY MOUNTAINS

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Összefoglalás - A munka a Dunántúli-középhegység karsztvízrendszerét képező Bakony csapadékviszonyait vizsgálta az 1991-95-ös időszakban. A csapadék fő jellemzőinek (időbeli eloszlás, intenzitás, makroszinoptikus helyzetek) meghatározása volt az első lépés. Ez alapján megállapítható, hogy a csapadékhullás a Bakonyban meglehetősen koncentrált. Ezt követően az 1990-es években bekövetkezett csapadéknövekedést vizsgálta a dolgozat. A folyamat okai jól elkülöníthetők a választott időszakban. A munka eredményeként megállapítható, hogy nem csupán a csapadék mennyiségi növekedése, hanem eloszlásának változása is segítette a karsztvíz rendszer regenerálódását. A csapadék növekedésének okait makroszinoptikus helyzetek szempontjából is értékeli a tanulmány.

Summary - This paper presents the results of the research, which has analysed the precipitation of Bakony Mountains (part of Transdanubian karst system) between 1991 and 1995. At the same time we have studied the infiltration too. The first step was to study the temporal distribution of the heavy amount of precipitation (occurrence, intensity, macrosynoptic situations). Based on these data we have concluded, that the precipitation in this area is concentrated. As the next step of the investigation we have determined the causes of the increased amount of mean precipitation of the first half of 1990's. We could easily separate these in the studied period. It seems that this increase of precipitation is a part of a trend. By the the study we can conclude, that in the regeneration of karstwater-system of the Transdanubian Mountains not only the increasing of amount of precipitation played an important role, but the change of its temporal distribution too. The causes of this increase of precipitation were compared with macrosynoptic situations.

Key words: dry period, increasing of precipitation, macrosynoptic types, parameters of precipitation, main periods of precipitation

INTRODUCTION

The Transdanubian Mountains reserve large amount of karst water, which is supplemented by precipitation. Its exact budget is not yet well defined, because to determinate the amount of water input and output is very difficult. To determinate precisely the water budget, the climatological parameters of the area must be studied as well. Therefore, this work could have large importance in the infiltration researches.

We examined the data of the years 1991-95 at Bakonybél-Somhegypuszta climatological station.

The Bakony Mt. is only a part of the whole infiltration area (*Lorberer,* 1986). We have chosen this territory, because this is the only one region, where climatological stations exist even on higher altitudes with the necessary density. Therefore, the modelling of macrosynoptic situations, the resulted precipitation and the history of a single rain was possible. We have chosen this station, because it is in the centre of Bakony Mt., and all those climatological effects are mixed here, which are dominant in other climatological stations. For example at Farkasgyepű station the oceanic effects are dominant (the climate of Bakonybél is mostly similar to this point, but already transitional), whilst at Veszprém and Mencshely the Mediterranean ones. In the case of Zirc the climate is influenced by the geographical situation, as far as it is located in an enclosed basin. Therefore, this station is protected from the westerly and southerly winds causing interesting changes in temperature and precipitation. In the point of precipitation at Zirc the Mediterranean effects dominant. This statements are confirmed by the Mediterranean index of this climatological stations too (*Koppány and Unger*, 1992). Of course, these differences are inside the continental climate, prevailing in the Bakony. The continental effect is turn into strong in the closed basins, and the mountain is appearing at the tops and plates of Bakony. We have chosen this period, because it both involves the dry period, which started at the end of the 1970's, and the wet period, which started at the autumn of 1993. The other reason was, that the radical changes in the measurement system of meteorological stations took place later, only after 1995.

DETERMINATION OF THE MAIN PERIODS OF PRECIPITATION

It is a fundamental question, whether we can typify the activity of precipitation and whether there is such macrosynoptic situation, which mostly determinates the quantity of precipitation.

The mean precipitation at the chosen meteorological station was 827 mm between 1901-50, but between 1951-1998 it was only 784 mm. It was 755 mm in the examined 5 years. In the driest year only 683 mm precipitation was detected, but during the wettest year it was 871 mm (*Table 5*).

According to our study in 43-44% of the days out of the year can be considered as rainy at 400 m a.s.l. in the study area. This value varies only slightly year by year, and it means that 2 days out of 5 are rainy. Contrary, on most of these wet days the precipitation is not heavy (it remains below 5 mm/day). Heavy quantity of precipitation occurs only on the 31% of the wet days (*Table 1*).

Table 1 The distribution of the different amount of precipitation by classes (mm/day) in days within the wet days (%)

Classes	*Under 0.5 mm*	*0.5-5 mm*	*5-10 mm*	*Above 10 mm*
%	20	49	16	15

It means, that heavy amount of precipitation occurs mostly in well-defined periods. But it is more important question what is the proportion of yearly precipitation on these wet days. Using this approach, the 79% of the total amount of precipitation of the investigated five years were measured on those days, which received more than 5 mm precipitation (*Table 2*).

Table 2 The portion of the different amount of precipitation classes within the mean precipitation (%)

Classes	*Under 5 mm*	*5-10 mm*	*Above 10 mm*
%	21	23	56

According to these data 79% of the total precipitation is realised on the 31% of the wet days, which is only 1/7-1/8 part of the whole investigated period. We can conclude, that the precipitation is very concentrated in time. Based on these results, in the following we examine the precipitation over 5 mm/day.

The following step of the investigation was the determination of that Péczely's macrosynoptic situations (*Péczely,* 1961), which caused heavy amount of precipitation. The Károssy's classification was used as source (*Károssy,* 1998) (*Table 3*).

Table 3 Macrosynoptic situations according to *Péczely* (1983)

Number of macrosynoptic situation	***Code of macrosynoptic situation***	***Description of macrosynoptic situation***
1	mCc	Hungary is in the rear of an East European cyclone
2	AB	Anticyclone over the British Isles
3	CMc	Hungary is in the rear of a Mediterranean cyclone
4	mCw	Hungary lies in the fore part of a West European cyclone
5	Ae	Anticyclone east of Hungary
6	CMw	Hungary lies in the fore part of a Mediterranean cyclone
7	Zc	Zonal, cyclonic
8	Aw	Anticyclone extending from the west
9	As	Anticyclone south of Hungary
10	An	Anticyclone north of Hungary
11	AF	Anticyclone over the Fennoscandinavian region
12	A	Anticyclone over the Carpathian Basin
13	C	Cyclone over the Carpathian Basin

By this approach the precipitation seems even more concentrated in time (*Table 4*). Studying the table one could see that cyclonic situations occurs in one third of the whole period, but during this time occurs 95.4% of the days with heavy precipitation (over 5 mm/day). Therefore, they occur at this time 97.1% of heavy precipitation. This is the 79.6% of sum of precipitation. (This value could be larger, because we did not calculate with the precipitation below 5 mm/day.)

During the classification of macrosynoptic situations some problems rise. The most typical difficulty originates from the European macrosynoptic situation, which presents anticyclonic field for Carpathian Basin. But in contrary, it is on the edge of this field; therefore, the weather is controlled by a cyclone. In these frequent cases the centre of the anticyclones is situated over the British Isles, and it is converted to the whole Carpathian Basin too. But on the edge of this anticyclone is a moving cold front, with regular cloud system. In these cases Hungary receives heavy amount of precipitation, with a distribution like of the meridional cyclone's cold front. The situation is similar, when north of Carpathian Basin is an anticyclone, so the country is situated on its southern edge, while over the Balkan Peninsula a Mediterranean cyclone is formed. Its result is a large amount of precipitation, which carries the characteristics of a warm sector of a Mediterranean cyclone.

Interesting phenomena is the orographic occlusion caused by the cold air flowing into the Carpathian Basin. We believe that it can not be described as a simple anticyclonic situation, and it can be easily separated from it.

Table 4 The proportion of the several macrosynoptic situations by different respects. The main situations are written by bold

	Frequency of a given macrosynoptic situation				***Amount of precipitation***		
	During 5 years		***In the case of heavy precipitation***		***mm***	***Proportion (%)***	
Code of macrosynoptic situation	***Number of days***	***Frequency (%)***	***Number of days***	***Frequency (%)***		***of precipitations over 5 mm***	***of all precipitation***
1	201	**11**	70	**29.4**	745.3	**24.1**	**19.7**
2	170	9.3	2	0.8	25.9	0.8	0.7
3	39	**2.1**	11	**4.6**	145.4	**4.7**	**3.9**
4	95	**5.2**	22	**9.2**	239.7	**7.7**	**6.4**
5	235	12.9	2	0.8	15.9	0.5	0.4
6	101	**5.5**	57	**23.9**	798.6	**25.8**	**21.2**
7	46	**2.5**	13	**5.5**	134.4	**4.3**	**3.6**
8	257	14.1	3	1.3	5.7	0.2	0.2
9	95	5.2	0				
10	149	8.2	3	1.3	28.7	0.9	0.8
11	99	5.4	1	0.4	14.2	0.5	0.4
12	246	13.5	0				
13	93	**5.1**	54	**22.7**	942.4	**30.4**	**25**
Sum	1826	100	238	100	3096.2	100	82
Proportion of cyclonic situations (%)		31.5		95.4		97.1	79.6

The classification of those situations is disputable, when the cyclone has no well described centre or front, but the moistureful air streams into the Carpathian basin in a relatively well ordered form (19 August 1995). (This air mass usually originates from Mediterranean See, or from Black See.) Sometimes it gets active in the Basin (28 November 1995). At this time the distribution of precipitation looks like in the case of cyclonic situation. The stream of airflow is usually not so systematic, and the distribution of precipitation presents it well (17 September 1995).

Further classification problems occur at summer times, when a cold front remains in the same place for awhile or on the south edge of a meridional cyclone a Mediterranean cyclone is formed. In these cases the precipitation is not like as a cold front of a meridional cyclone. The classification of that cyclone is disputable too, which is formed over Vizcaya Gulf, moves towards the Adriatic Sea and gets active over the northern part of the latest one. (Meridional or Mediterranean cyclones?) The precipitation pattern of these is very different from the meridional cyclones.

Sometimes it happens that the different parts of the same investigated area are influenced by different sectors of a cyclone, therefore, the distribution of precipitation is different too (on 21 and 24 October 1992, 31 December 1994, 8-9 August 1995).

We have thought, that these situations are falling under the other categories so we reclassified these. In these cases the amount of precipitation was 20% of the sum of precipitation, and 29% of the heavy (over 5 mm/day) precipitation. Therefore, we believe that we should find a new way in reclassification of macrosynoptic types of Carpathian Basin *(Table 5).*

Some problem can be solved with Bodolainé's characterisation (*Bodolainé*, 1983). (E.g. the "Cold air trough" category we can range to the most of the discussed situation, when there is anticyclone north or east of Hungary, and developing heavy precipitation.) But this classification we could not used, because we had not special data, need to this, and categories covering only the situations with extremely large precipitation, mainly in the summer half-year.

After finishing of this research we red a new study in this theme (*Hirsch*, 2000). By this work it seems, that M and Ms type is equivalent with the two of our problematical situation. (Passing cold front turn into Mediterranean cyclone and "Mediterranean cyclone", moved from Vizcaya Gulf.) By the two research could be registered the seasonable and spatial differences in case of heavy precipitation in Hungary.

We compared these problematical situations with Herz and Brezowsky (*Gerstengarbe and Werner,* 1993) characterisation, and examined the weather in Hungary during these types (*Bartholy and Kaba,* 1987). We found, that this characterisation is much more sensible and we can take by this the problematical situations to other categories. Thus in our opinion the Hess-Brezowsky types the better to the characterisation in Hungary, too.

Another problem derives from the rapid changes of weather, when during one single day two macrosynoptic situations occur. In this case it is difficult to distinguish the precipitation between these two.

Table 5 The distribution of heavy precipitation (over 5 mm/day) by macrosynoptic types (%)

Year / ***Macrosynoptic types***	***1991***	***1992***	***1993***	***1994***	***1995***	***Mean of 5 year***
1	**15.2**	**23.4**	**26.3**	**21.4**	**13.3**	**19.9**
3	1.6	1.1	2.2	3.1	10	3.6
4	9.9	3.3	9	6.4	3.8	6.5
6	**18.2**	**14.4**	**26.7**	**24.7**	**21.2**	**21**
7	0.9	3.4	1	3.6	8	3.4
13	**32.7**	**31.7**	**15.1**	**17.9**	**27.9**	**25.1**
Sum	78.5	77.3	80.2	77	84.2	79.4
Sum of heavy precipitations (cyclonic and non cyclonic too)	81.6	78.4	82.1	80.3	86.7	81.8
Yearly precipitation (mm)	683	715.8	756.9	748.4	870.7	755

The *Table 5* shows, that in some of the cyclonic situations caused heavy precipitation, and other situations caused very small amount of precipitation. Most of the yearly precipitation is resulted by three macrosynoptic types: No. 1, No. 6 and No. 13. (These refer to the rear front of a meridional cyclone, to the fore part of a Mediterranean cyclone and to a cyclone-centre situation.) They do not occur more often than the other cyclonic situations with the exception of No. 1. But if they appear in the region they frequently cause heavy and intensive precipitation. This statement is not right for the No. 1 situation, but it is much true for No. 6 and No. 13. From the point of precipitation the No. 3, No. 4 and No. 7 situations could be considered as "complementary" ones. (These refer to the cold front of a Mediterranean cyclone, to the warm front of a meridional cyclone and to zonal cyclone.) Their incidence is little bit lower, than of the members of the above mentioned group (No. 6 and No. 13), but they cause smaller proportion and lower intensity of heavy precipitation. The No. 1 situation carries the characteristics of both groups. When it appears it usually causes small amount of precipitation just like the No. 3, No. 4 and No. 7 types, and its intensity is very similar to this group. But at the same time it prevails very often, and as its result, the amount of precipitation due to this situation is very similar to the proportion of No. 6 and No. 13. So we think, that the No. 1 type is falling in the same group with these two.

We must mention that some of anticyclonic situations cause more precipitation than certain cyclonic ones. It is true even after corrections (i.e. after re-coding some cyclonic situations, which were previously considered as anticyclonic). It caused by the fact, that some anticyclonic situations form such currents, where the conditions are very favourable for precipitation formation. If we study these situations, we can state that – besides the case of centre above the Carpathian Basin – in every anticyclonic situation some heavy precipitation was measured in the studied period. But the wet of the No. 2, No. 10-11 situations rises (i.e. anticyclone over the British Isles, anticyclone north of Hungary and anticyclone over the Fen-Scandinavian region). Their relatively high precipitation can be explained by different causes. The No. 2 situation causes precipitation during summer time, as far as in this situation moistureful, unstable current arrives from the Mediterranean region to the Carpathian Basin. It causes local showers, thunderstorms. The No. 10 and No. 11 situations produce large amount of precipitation in winter lasting for several days. It can be explained by that the cold air in their current is mixed with the warm air within the Basin (No. 10 situation), or with the warm and wet air masses of a Mediterranean cyclone situated south of Hungary (No. 11 situation). If this mixture of air masses is enough strong, it will result an occlusion front and the formation of a cyclone (No. 10 situation), or formation of a Mediterranean cyclone or movement of it to the Carpathian Basin (No. 11 situation). If these processes are not enough well defined and systemathical, we should classify these situations as anticyclonal, though, they result heavy amount of precipitation.

EXAMINATION OF THE PARAMETERS OF THE PRECIPITATION

From the above presented data one can see, that the amount of precipitation during the examined five years was increased continuously (only in 1994 was a slight decrease, but then it increased considerably) (*Table 5*). It arises the questions that (1) what caused this increasing tendency and (2) which parameters changed simultaneously.

First of all we considered that the increase of mean precipitation followed the increasing number of cyclonic situations simultaneously (*Fig. 1*). But the latest one did not cause the increase of precipitation. The appearance of cyclonic situation was the rarest in the first, dry year (1991), then it became more abundant for a while, but later the number of its appearance decreased again, thus, in the last year (1995) its number was almost like in 1991. This statement is right for the No. 6 and No. 13 situations, which result most of the precipitation. The No. 1 is exception of it, but after 1994 this showed well-defined decrease too. Thus, the frequency of No. 1, No. 6 and No. 13 situations followed the changes in number of cyclonic situations. The budget of the five years and the number of cyclonic macrosynoptic situations stagnated. The result, if we try to connect the number of different macrosynoptic situations with the yearly precipitation, that there is not relationship between them.

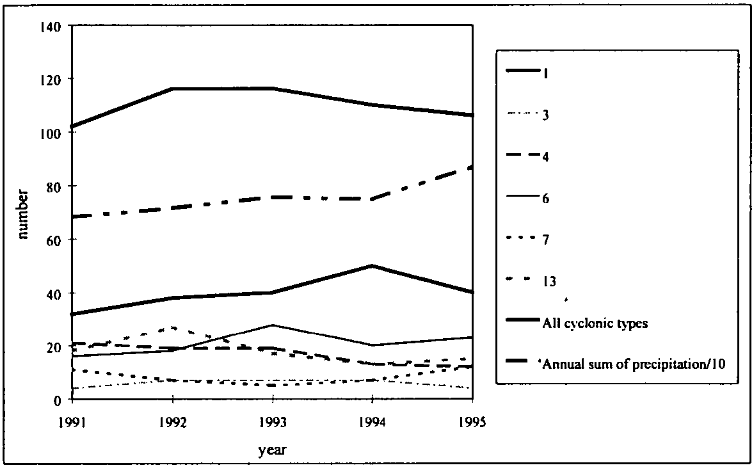

Fig. 1 Variation of the number of different macrosynoptic types and the annual sum of precipitation (mm), between 1991-1995

Between the number of wet days and the mean precipitation is a direct proportion, which can be demonstrated well using the number of days with the heavy precipitation (over 5 mm/day) instead of the number of wet days (*Fig. 2*). The number of wet days or the day with heavy precipitation changes simultaneously with the amount of yearly precipitation with the exception of the year 1991. This relationship between the number of wet days and yearly precipitation is strong since 1993, but it can be considered as rather strong connection since 1992 between the heavy and yearly precipitation respectively. In this last case the relationship is strong enough to identify certain macrosynoptic situations too.

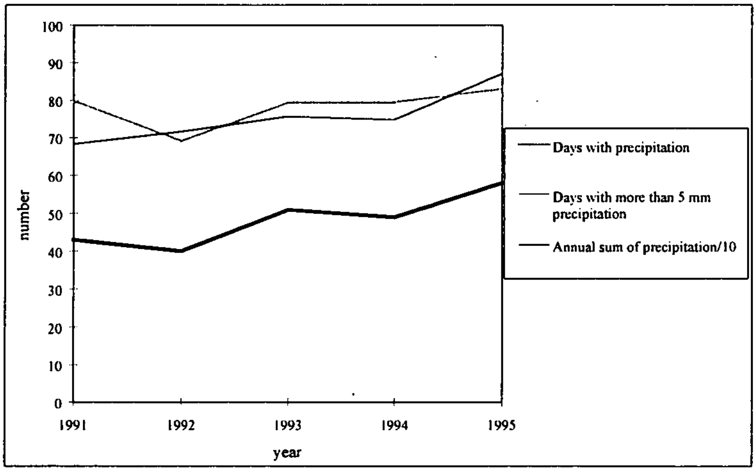

Fig. 2 Variation of the number of days with different amount of precipitation and the annual sum of precipitation (mm), between 1991-1995

After comparison the distribution of days with heavy precipitation with the number of different macrosynoptic situations, in the case of No. 13 and No. 6 situations we have found out that the number of days with heavy precipitation changed with the yearly precipitation after the year of 1992 (*Fig. 3*). However, there is no tendency between the changes in the number of days with heavy precipitation and the yearly precipitation in the case of No. 1 situation, similarly to the other situations. (The only one exception is the No. 3, but it caused only small amount of precipitation.)

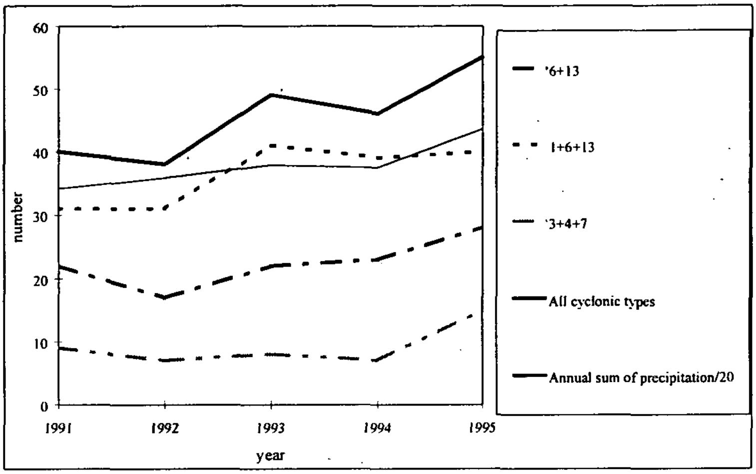

Fig. 3 Variation of the number of cases with precipitin over 5 mm/day by the cyclonic types and the annual sum of precipitation (mm) between 1991-1995

The causes of the increase in number of all days with heavy precipitation can be well defined at the centre and at the end of the studied period. The increase in the number of those situations (i.e. No. 1, No. 6 and No. 13), that resulted most of the precipitation, increased at the centre of the period and it can be connected with the short stagnating period of 1994. But the increase in number of days with heavy precipitation during the wettest year of 1995 is in relationship with those cyclonic situations (i.e. No. 3-4 and especially No. 7) which caused small amount of precipitation previously. So, there is an ordinal relation, but the changes are influenced by other causes, too. These are as follows.

The proportion of the above mentioned two parameters (i.e. the number of different situations and the number of their heavy precipitation days) is the "wetness" of a situation. This is an intensity value of the precipitation (*Fig. 4*). The "wetness" of all cyclonic situations correlates with the number of days with heavy precipitation, and since 1992 with the yearly precipitation as well. The year of 1991 is an exception from this point too: certain situations were disproportionately rainy in comparison with the yearly precipitation. (But, as we have already mentioned in this year the number of those cyclonic situations, which usually caused precipitation was very low.) The changes of different macrosynoptic situations show even larger differences than in the case of the previous parameter. The distribution of No. 3-4 and No. 7 situations is very similar to the distribution of the number of days with heavy precipitation, and their number largely increased in 1995. The wetness of No. 6 and No. 13 situations decreased until 1993, but than it increased considerably. The No.1 situation shows different distribution. Their total wetness (No. 1, No. 6 and No. 13) is changes with the days with heavy precipitation, as well as of No. 3-4 and No. 7 situations.

It means, that the cause of the increasing of the precipitation was the growing "wetness" (intensity value) of the different macrosynoptic situations, not their number.

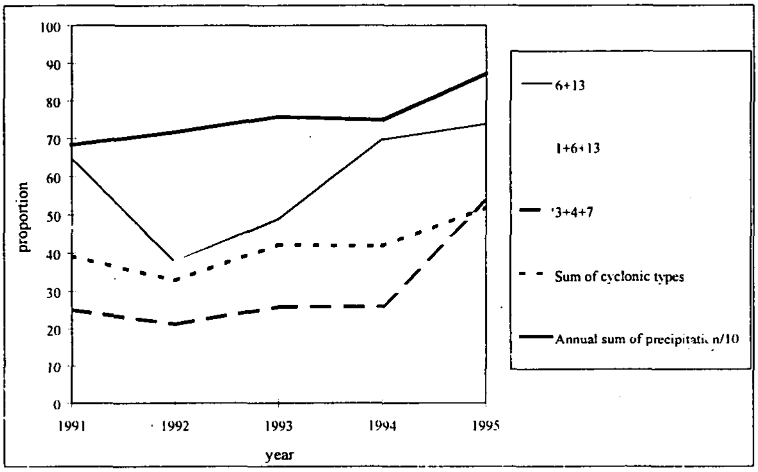

Fig. 4 Variation of the proportion of the cases with precipitation over 5 mm/day by the cyclonic types and the annual sum of precipitation (mm) between 1991-1995

The analysis of the average of precipitation of the heavy precipitation days (of certain macrosynoptic types) gives an intensity value too (*Fig. 5*). This value changed slightly in the case of total cyclonic precipitation: it was very high in the first two year, than after a decrease it stagnated and later it increased a while. But if we study this value in every single macrosynoptical type, we can conclude that it is very varied. It is especially right for those situations, which caused very high intensity precipitation (No. 6, No. 13 and in some cases No. 3 and No. 7). One out of these situations is cyclone-centres (resulting most of the precipitation of the Carpathian Basin) and two are Mediterranean cyclone. The average intensity of precipitation of these two athmospheric phenomena changed complementary. The precipitation intensity of meridional cyclons (No. 1 and No. 4) has changed more slightly in the examined period. The intensity of heavy precipitation resulted by No. 1, No. 6 and No. 13 situations is decreased during the analysed period, but it increased in the case of No. 3-4 and No. 7 situations respectively. Thus, the precipitation intensity of these two groups changed complementary, therefore, it resulted a slight decrease of precipitation intensity. (This decrease can be explained as it follows: though the intensity of the second group grew rapidly and it decreased only slightly in the case of the first group, but this latest group – i.e. No. 1, No. 6 and No. 13 – results most of the precipitation.) However, this general recession does not mean that heavy storms and precipitation are rare. (The largest precipitation intensity was recorded in 1995!)

During cyclonic situations the intensity values are mostly higher than the values of the all heavy precipitation. It means, that the cyclonal conditions results larger intensity of precipitation than the local effects, thus, the larger amount of precipitation in the Bakony Mt. is always in connection with cyclonic situations. The only one exception was in 1991. In this year the anticyclonal situations played important role in the formation of precipitation, and the average of their heavy precipitation was larger, so it were more intensive, than of the cyclons in the same year.

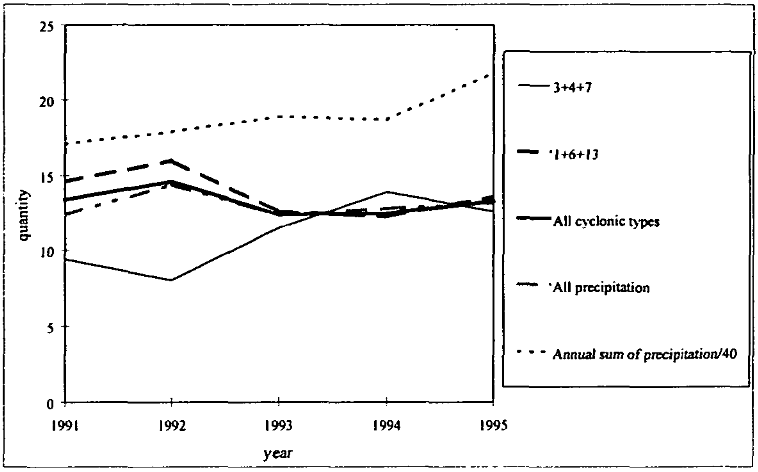

Fig. 5 Variation of the average intensity (mm) of the precipitation over 5 mm/day by the cyclonic types and the annual sum of precipitation (mm) between 1991-1995

THE CAUSES OF THE INCREASE OF PRECIPITATION

First of all we have to find the causes of the dry weather of the first year. In 1991 the number of cyclonic situation was very low, but at the same time the number of wet days was considerably large. It means, that the rare cyclonical situations caused precipitation in larger proportion. But the number of heavy precipitation was very low, though in these rare cases the precipitation intensity was the second largest within the studied period. It is worth to note, that relatively large proportion of the heavy precipitation was realised in anticyclonical situations.

In the next year (1992) the number of the cyclonic situations was increased rapidly reaching its maximum value, but the number of the wet days, and heavy precipitation days reached the lowest number within the 5 years. Thus, the abundant cyclonic situations caused precipitation only sometimes, but the intensity of heavy precipitation reached its maximum value. These resulted larger amount of mean precipitation than it was in the former year. In this year the cause of increased amount of precipitation is the increased intensity of heavy precipitation.

In 1993 new processes started, which lasted until the end of the examined period. The number of the cyclonic situations reduced, but the number of wet days – and the heavy precipitation too – increased. It means, that the frequency of wetness grew. As the amount of precipitation was growing the No. 13 situation became more abundant. Mainly it caused, that the group of No. 1, No. 6 and No. 13 situations resulted more precipitation too. The increased amount of mean precipitation in 1993 we can be explaining with growing of wetness of this group.

At the same time the intensity of the heavy precipitation was significantly reduced. Therefore we supposed that the increase of mean precipitation had other causes than in the previous year. After this reduced the intensity of heavy precipitation a little bit increased, but the value was almost the same as it was before.

These processes existed during the rest of the studied period, but in the 1994 they were temporarily stopped. It shows relationship with a slight decrease of yearly precipitation. But the increased amount of mean precipitation in 1995 can be explained by the increasing wetness of group No. 3-4 and No. 7 situations. The new research (*Hirsch,* 2000) confirmed too, that the 4 and 7 situations antecedents of types with considerable precipitation. Although its precipitation is not large, it seems there is not large yearly precipitation without these.

We think, that the increase of precipitation is part of a process. The causes of the changes can be justified by the combination of the analysed parameters.

It seems, that at the beginning the cause of increased precipitation is the increasing of cyclonic situations, and henceforth their growing intensity (first of the No. 1, No. 6 and No. 13 group, than after of the No. 3-4 and No. 7).

As a result the yearly precipitation was increased, and the number of heavy precipitation became larger too, but their intensity was decreased.

We must be careful when extrapolate these result for longer periods, because the examined period was too short, but may be the changes of this examined parameters show the shift of weather from a dry to a wet period. The same changes in precipitation and infiltration were observed all over Transdanubian Mountains since autumn of 1993. This autumn and the subsequent winter were much wetter than the average of the previous years.

CONCLUSIONS

Based on this analysis we could conclude that the occurrence of heavy precipitation and the prevailing macrosynoptic situations are temporally very concentrated in the Bakony Mountain.

In the examined period the mean precipitation was increased. The causes of these processes were very complex, and they differed in the first half and the second half of the studied period, the latest means the end of the dry period. Within this second half two crucial points could be distinguished. The continuous increase of precipitation seems to be a part of a process. It is probable that the different studied parameters and the mean precipitation changes similarly even during a longer period, therefore they could indicate the longer dry and wet years.

The number of heavy precipitation and the yearly precipitation were changed simultaneously, but the intensity of the first one was reduced. It means, that both the frequency of precipitation under 5 mm/day and the extremely high precipitation were reduced. It is well known, that from the point of infiltration booth extremities are not favourable. Therefore, not only the increasing precipitation, but also its changing intensity played an important role in the quick regeneration of the karst-water system of Transdanubian Mountains.

This analysis should be continued. We have to study whether these statements are valid for previous periods, and in what extent they continued after 1995.

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HEAVY METAL CONTENT OF SOME HUNGARIAN AND ENGLISH KARST SOILS

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Összefoglalás - A karsztokon kialakult talajok nehézfém-tartalmának vizsgálata nagy jelentőségű, mivel a Föld ivóvizeinek 25 %-át karsztvizek szolgáltatják. A szennyeződések (különösen a nehézfémek) igen veszélyesek a karsztos területeken. Amennyiben az oldatba kerülő nehézfémek a talajon keresztül szivárogva bekerülnek a karsztvízbe, az veszélyforrást jelent az ivóvizet használó lakosság számára. A nehézfémek többsége száraz és nedves ülepedésből származik, amelyek a talajok elszennyezése mellett azok elsavanyodásához is hozzájárulhat. A talajokban a nehézfémek a talajalkotó részecskékhez kötődnek. A nehézfémek talajoldatba kerülését a talajok megkötő képessége befolyásolja. Ez elsősorban a talajok kémhatásától, szerves-anyag- és agyagtartalmától, azaz a talajok puffer-kapacitásától függ. A nagy puffer-kapacitással rendelkező talajokban a veszélyes fémek a talajalkotókhoz kapcsolódva felhalmozódhatnak, így azok a talajoldatba kerülve nem érik el a karbonátos alapkőzetet. A nehézfémek mobilitása a talajok kémhatásának és szervesanyag-tartalmának csökkenésével párhuzamosan általában növekszik. A tanulmány néhány angol és hazai karsztos területen ismerteti a talajok nehézfém-tartalmát. A vizsgálatok a talajok kémhatása, szerves-anyag- és nehézfém-tartalma közötti kapcsolatot tárják fel. Az irodalomban kevés adatot találunk a karsztos területek talajainak nehézfém-tartalmáról, ezért a dolgozatban szereplő nehézfém szennyezettségi adatok jó alapot szolgáltatnak a további vizsgálatokhoz.

Summary - The heavy metal content of karst soils is a significant aspect of karst water because 25% of drinking water comes from the karstwater of the world. The pollution (especially the heavy metal pollution) of the soils is dangerous for karst areas. If the metals pass from the soil into the karst water it will be unhealthy for the population. Much heavy metal is inherited from dry and wet deposition. Acid dry and wet depositions bring pollution materials and give rise to acidification of soils. Soils which have appropriate characteristics can bind the heavy metals to the different soil particles. This power to prevent the heavy metals reaching soil solution mainly depends on the pH, the organic matter and clay content of the soils, namely on the buffering capacity of the soil. The soils with high buffering capacity can accumulate the dangerous metals in the soils and do not permit them to go to soil solution and thus to reach the limestone bedrock and finally the karst water. Generally, the mobility of heavy metals increases with decreasing pH and decreasing organic matter content of soils. Our paper presents the heavy metal content of karst soils in some English and Hungarian karst territories. The analysis of soils attempts to detect the connection between the organic matter content, pH and the heavy metal content of these soils. In the karst-literature we have as yet few data concerning heavy metal contamination of karst soils. Our data indicate the pollution level of karst soils. These data are a basic point for further investigations.

Key words: karst soil, heavy metal contamination, British Karsts, Aggtelek Karst, Mecsek Mountains

METHODS

We collected soil samples on Hungarian and English karst areas. The Hungarian samples came from the Aggtelek Karst and Mecsek Mountains; the English ones are from limestone areas of Northern England (*Figs. 1-5*). The studied area on Aggtelek Karst is in a National Park; the investigated western part of Mecsek Mountains (with the karstified Triassic limestone) is a projected protected area. There are differences in precipitation and height above sea level (Aggtelek area: 310-480 m, Western Mecsek: 300-450 m) in the two investigated Hungarian areas. The annual precipitation is 650-700 mm on Aggtelek Karst and 700 mm in Western Mecsek. The karst areas of Mecsek Mountains are situated in western direction from coal mining places (the main wind direction is north-west). Aggtelek Karst is situated south-east from Slovakian industrial areas and the next to this area the main Hungarian chemical industry was developed. Acid deposition is higher here than in the Mecsek Mountains.

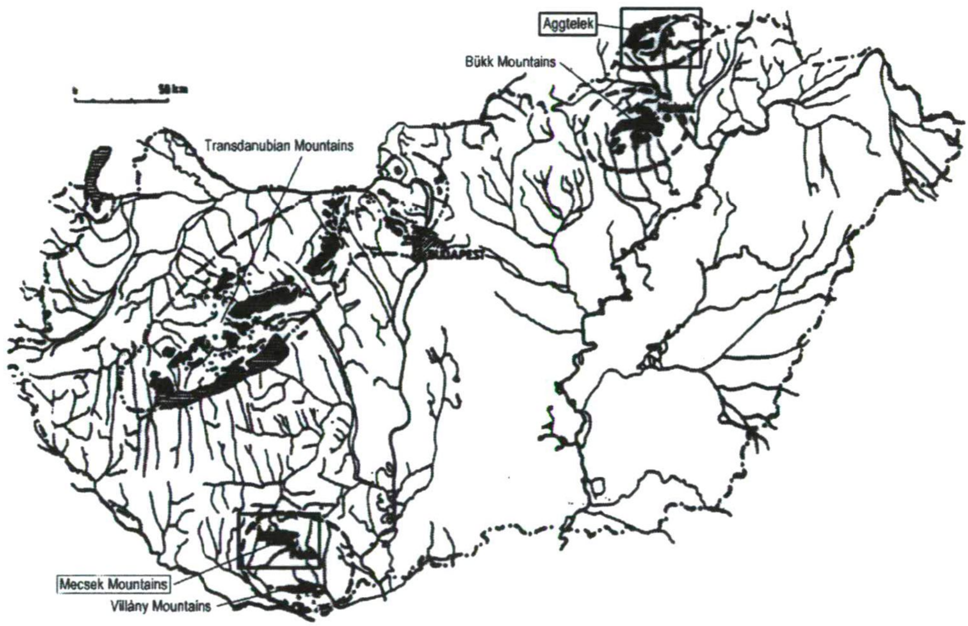

Fig. 1 Limestone regions in Hungary

Each collected soil occured on limestone bedrock. The soils are mainly rendzinas or rendzina like soils (unconsolidated) on Aggtelek Karst but we have some brown forest soil as well. The soils of Mecsek Mountains are mainly brown forest soils with clay illuviation (better consolidated), and there are some rendzinas. The Hungarian samples were collected in areas that represent different ecological conditions: different type of forests and fields. The English soils are thin soils covering limestone pavements (Carboniferous limestone). Some of them were collected on limestone pavements areas where there was mining activity (mainly lead) in the past. We have some English samples from dolinas as well. The thickness of the soils is mainly only 40 cm in the case of rendzinas, and they are mixed with limestone fragments (40-60%). The brown forest soils are deeper and usually there are no fragments in them. We chose the upper 10 cm soil layer to make comparison of pH, organic matter and heavy metal content of the soils in the different karst areas of Hungary and England. The organic matter accumulates near the surface and the heavy metals bind to humus colloids (We have data from deeper layers, too, but the main accumulation horizon is the uppermost level (A_0 level)).

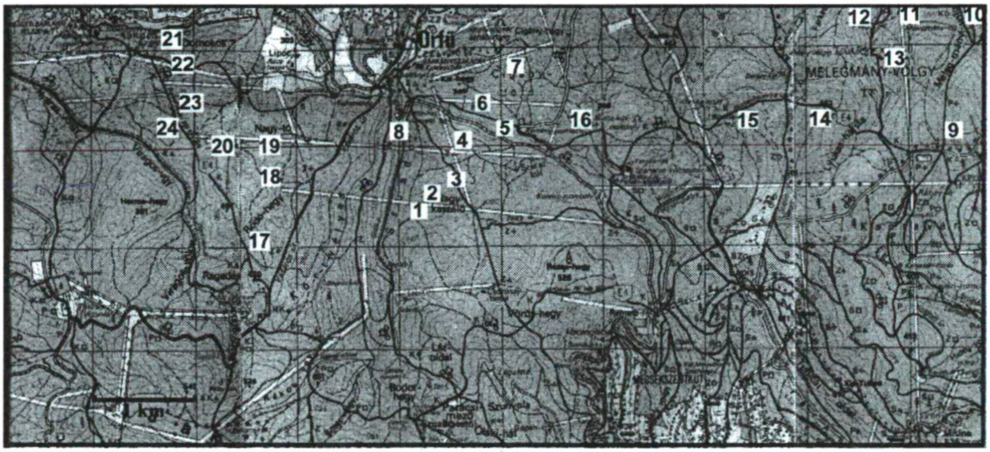

Fig. 2 Sample sites in Mecsek Mountains

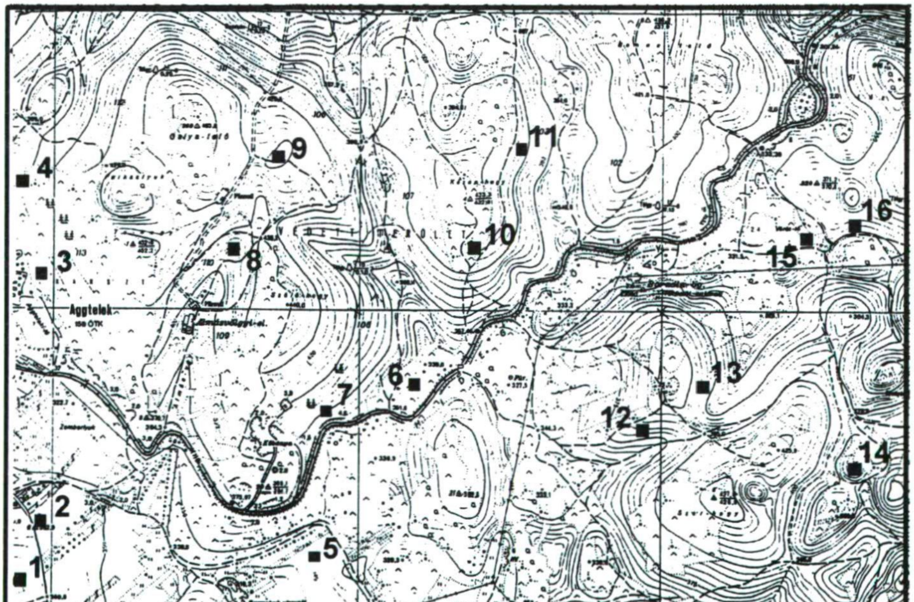

Fig. 3 Sample sites in Aggtelek Karst

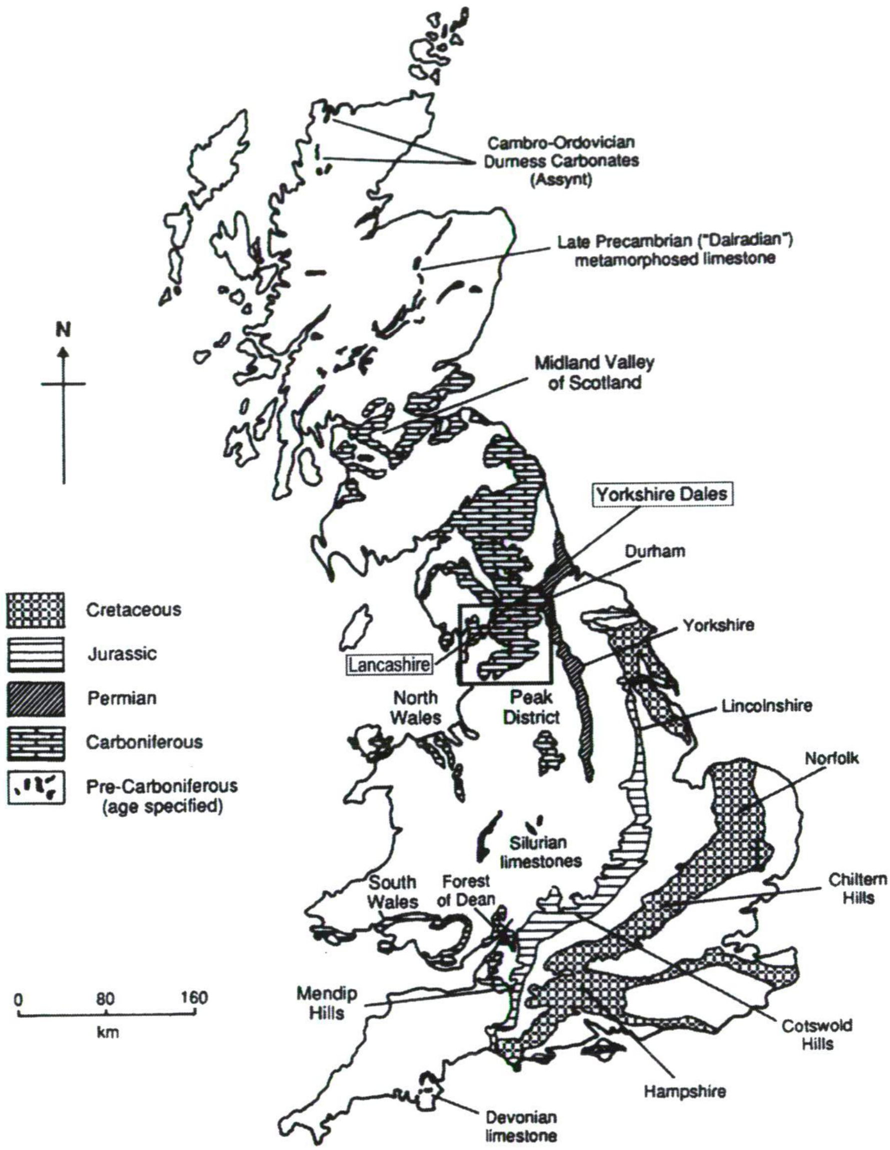

Fig. 4 Limestone regions in England

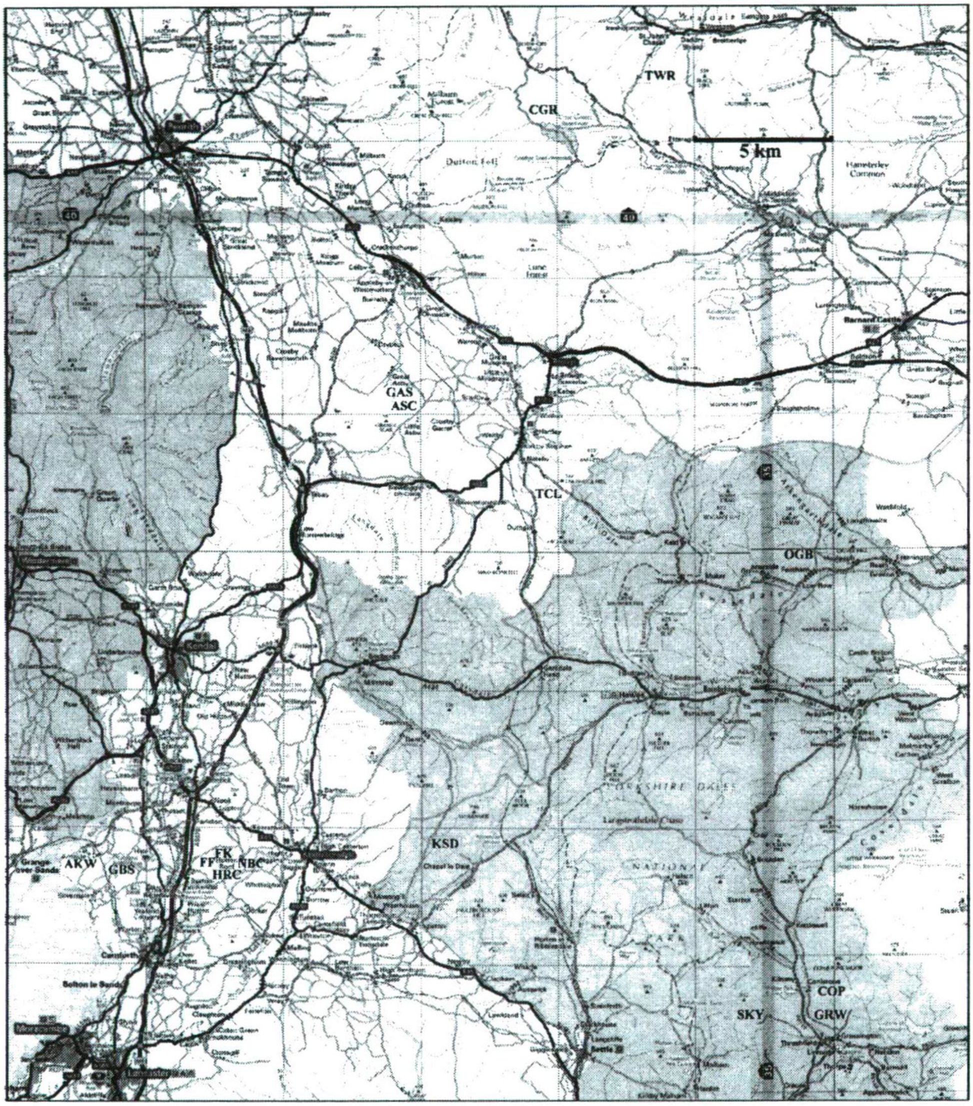

Fig. 5 Sample sites in England (Yorkshire Dales and Cumbria)

The pH was measured in distilled water with a digital pH-meter. The soil water ratio is 1 : 2.5 (6 g soil and 15 cm^3 water). The organic matter was oxidized in acid solution by $K_2Cr_2O_7$ and measured by spectrophotometer (Hungarian samples and the English samples: GAS 1, 5, TCL 5, 6, FF 7, NBC 2, COP 3, 4, HRC 9, 11, ASC 3.) The other English samples were measured by titration after $K_2Cr_2O_7$ oxidization. The heavy metals were extracted from all soils by aqua regia and measured by atomic adsorption spectrophotometer (Hungarian samples) and by ion-chromatography (English samples). This means that except for the heavy metals bound to the silicate mineral, all heavy metal content was measured. So we determined that part of the heavy metal content of soils which can be mobilized if the conditions of the environment change in some way.

DISCUSSION

Based on our earlier investigation the heavy metal content of karstic soils in Hungary is higher than it should be originating from the parent rock alone (*Keveiné Bárány et al.*, 1999). *Kádár* (1991) has already found that the near-natural environments in Hungary contain much more heavy metals than they would have if the heavy metals originated only from the parent material.

The heavy metal content of limestone is originally not too high. After *Kabata-Pendias and Pendias* (1984) the heavy metal contents of limestone and dolomite are: Cu: 2-10; Co: 0.1-30; Cd: 0.035; Ni: 7-20; Pb: 3-10 ppm. After *Merian*'s investigation (1984) the average concentration of heavy metals in limestone is the following: Cu: 4; Co: 2; Cd: 0.165; Ni: 15; Pb: 5; Zn: 23; Mn: 700 ppm.

After *Xiandong and Thorton* (1993) the multi-elements contamination of soils (for example of brown earth on the carboniferous limestone) is affected by underlying mineralised rock, by mining activities producing widespread contamination and by smelter pollution. The metal contamination of large areas of agricultural soils in England comes from mining, too (*Colbourn and Thorton*, 1978).

Brümmer et al. (1991) have established that increase of metal mobility is related to pH value: the different heavy metals go at different pH values to solution: Cd pH < 6.0-6.5; Mn pH < 5.5; Zn pH < 5.5; Ni pH < 5.5; Co pH < 5.5; Al pH < 4.5; Cu pH <4.5; Pb pH < 4.0; Fe^{3+} pH < 3.5 can be mobilized. From this it is clear that the lower pH values help the mobility of metals.

The classification of soil reaction in the different areas *(Table 1)* shows us that about half of the examined soils in Mecsek and Aggtelek Karst are acid and we can find strongly acid soils as well. The English samples are mainly weakly acid and acid.

The heavy metal contents, pH and organic matter content of the soils are in *Tables 2, 3, 4* as well as pollution limiting values.

Table 1 Classification of soil reaction

Chemical reaction after Stefanovits, (1992)	***Number of soil samples***		
pH(H_2O)	*Aggtelek*	*Mecsek*	*England*
strongly acid (pH below 4.5)	2	1	4
acid (pH 4.5-5.5)	**8**	**11**	**14**
weakly acid (pH 5.5-6.8)	3	8	**16**
neutral (pH 6.8-7.2)	1	2	3
weakly basic (pH 7.2-8.5)	2	1	4
Sum total	16	23	41

Table 2 Heavy metal content, pH and organic matter content of soil samples in Aggtelek Karst

Aggtelek	***Ecological***	***Heavy metals (ppm)***							***pH(H_2O)***	***Org. mat.%***
sample	***condition***	***Cd***	***Pb***	***Ni***	***Co***	***Cu***	***Cr***	***Mn***		
1	oak	**2.44**	96.0	**60.9**	22.7	**226.3**	54.0	678.8	5.49	15.1
2	stubble	0.48	29.9	23.9	14.5	**221.7**	40.6	636.0	7.66	16.3
3	field	**1.20**	43.9	**65.1**	17.6	**226.1**	72.2	636.7	7.31	12.6
4	oak	0.85	36.9	**56.0**	14.1	**204.3**	69.5	437.0	5.00	12.7
5	field	0.68	68.0	**48.1**	24.3	**222.8**	56.3	611.0	5.35	26.6

Table 2 (continued)

Aggtelek sample	*Ecological condition*	*Heavy metals (ppm)*							*pH(H₂O)*	*Org. mat.%*
		Cd	*Pb*	*Ni*	*Co*	*Cu*	*Cr*	*Mn*		
6	field	0.90	47.0	**46.4**	19.7	**222.2**	55.0	607.7	5.71	28.0
7	pine	0.90	42.4	**53.8**	14.3	**219.3**	67.9	502.2	5.21	15.8
8	oak	0.87	46.9	**43.9**	18.2	**232.9**	53.3	539.0	4.33	19.3
9	oak	**1.90**	75.4	**55.0**	15.7	**262.6**	62.0	649.8	5.00	72.6
10	field	1.60	56.3	**54.5**	14.9	**240.4**	62.5	597.2	7.03	77.8
11	oak	**2.00**	57.4	**57.7**	13.9	**271.0**	67.4	604.4	6.29	43.1
12	oak	0.74	58.3	**55.7**	13.9	**275.3**	65.0	558.9	4.85	29.7
13	oak	0.95	68.1	**78.6**	27.1	**270.2**	**87.9**	488.9	4.93	33.0
14	oak	**1.13**	56.5	**44.3**	20.8	**251.7**	52.3	584.3	4.86	18.0
15	field	0.98	56.9	**48.7**	18.1	**279.6**	53.6	561.4	5.77	32.3
16	oak	0.76	53.6	**45.6**	13.7	**277.2**	55.7	516.0	4.40	44.0
background concentration		0,5	25	25	15	30	30			
pol. lim. value in Hungary		1	100	40	30	75	75			
pol. lim. value in England		1	50	30		50	50			

Table 3 Heavy metal content, pH and organic matter content of soil samples in Mecsek Mountains

Mecsek sample	*Ecological condition*	*Heavy metals (ppm)*							*pH(H₂O)*	*Org.mat.%*
		Cd	*Pb*	*Ni*	*Co*	*Cu*	*Cr*	*Mn*		
1	oak	0.30	26.0	34.0	17.0	12.0	19.5	761.5	5.11	6.09
2	oak	0.30	25.0	35.0	16.0	13.0	21.0	778.5	5.98	16.65
3	oak	0.60	26.0	**44.5**	12.0	17.0	27.0	599.0	5.69	10.82
4	oak	0.55	22.5	33.0	14.0	10.5	18.0	572.5	4.74	9.63
5	oak	0.20	22.5	35.5	9.5	13.0	20.5	448.0	5.21	9.27
6	beech	0.50	24.5	**41.5**	13.0	13.5	20.5	1054.0	5.97	9.7
7	oak	0.35	22.5	**43.0**	11.5	17.0	23.5	1100.0	6.78	15.42
8	beech	**1.45**	42.0	**49.0**	16.5	21.0	25.5	1525.0	7.46	35.38
9	oak	0.20	30.5	36.5	14.0	17.5	22.0	1152.0	4.54	6.95
11	oak	0.30	16.5	29.0	9.0	12.0	18.5	323.5	4.66	11.32
12	oak	0.95	35.0	**52.5**	14.0	17.5	32.0	948.5	6.07	19.61
13	oak	0.35	23.0	36.0	12.0	14.0	23.0	704.0	6.8	17.53
14	beech	0.15	23.5	35.5	12.5	13.0	20.0	696.0	4.89	16.6
15	beech	0.55	26.5	38.5	12.0	12.0	20.0	1395.0	6.07	15.24
16	beech	0.10	17.5	29.0	10.0	10.0	17.5	579.0	4.15	7.08
17	oak	**1.05**	28.0	33.0	17.0	10.0	19.0	810.5	5.08	7.9
18	oak	**1.05**	32.0	**54.0**	17.0	20.0	29.0	1242.5	6.67	15.2
19	oak	0.70	23.0	**52.5**	15.0	19.5	26.0	713.5	6.53	8.71
20	beech	0.10	21.5	32.5	13.5	9.5	18.5	649.5	4.9	9.73
21	oak	0.30	23.0	38.0	11.0	16.0	24.0	1122.5	6.98	9.5
22	beech	0.35	25.5	38.5	19.0	13.5	20.0	704.5	4.54	12.94
23	beech	0.25	25.5	34.5	14.5	10.5	18.0	950.5	5.34	12.09
24	beech	0.15	22.5	34.0	11.5	9.5	19.0	474.0	4.75	3.81
background concentration		0.5	25	25	15	30	30			
pol. lim. value in Hungary		1	100	40	30	75	75			
pol. lim. value in England		1	50	30		50	50			

Table 4 Heavy metal content, pH and organic matter content of soil samples in England

England sample	***Ecological condition***	***Heavy metals (ppm)*** *Cd*	*Pb*	*Co*	*Cu*	*Cr*	*Mn*	***pH(H_2O)***	***Org.mat.%***
GBS 005	lim. pav	0.00	**6630.4**	**51.2**	0.0	61.4	2240.0	6.3	3.77
GBS 006	lim. pav.	0.00	**3560.5**	0.0	25.9	**85.8**	4923.6	6.2	3.6
GBS 007	lim. pav.	0.00	**14837.0**	0.0	0.0	56.4	5731.8	6.21	0.8
KSD 1	mining area	0.00	**8237.3**	0.0	0.0	26.5	253.3	4.95	4.5
FK 1/A	doline	0.00	**9198.5**	0.0	0.0	34.9	1013.2	3.69	9.1
FK 1/B	doline	0.00	**4467.1**	0.0	0.0	64.2	2744.1	4.53	2.4
FK 2/A	doline	**387.60**	**7258.4**	0.0	0.0	26.6	0.0	3.93	6.7
FK 2/B	dolne	**752.20**	**8725.4**	0.0	0.0	27.8	961.1	4.69	1.7
FK 2/C	dolne	0.00	**16148.9**	0.0	**194.2**	**75.6**	1618.1	4.9	1.07
FK 3/A	doline	0.00	**8000.0**	0.0	0.0	19.0	0.0	4.26	5.08
FK 3/B	doline	**1965.40**	**22012.6**	0.0	0.0	73.5	3223.3	4.54	2
AKW 1	woodland	0.00	**7171.7**	**692.6**	64.9	55.9	938.0	5.56	5.5
AKW 2	woodland	0.00	**7146.3**	0.0	0.0	57.3	726.7	5.03	3.7
TCL 001	lim. pav.	**413.70**	**7068.5**	**142.7**	0.0	**93.0**	8915.8	5.62	4.7
TCL 003	lim. pav.	0.00	**13015.2**	0.0	**169.7**	**118.6**	13078.8	7.18	13.5
TCL 004	lim. pav.	0.00	**7720.5**	**47.3**	**279.5**	**97.0**	1048.0	6.84	6.6
TCL 007	lim. pav.	0.00	**2852.1**	**65.4**	**120.7**	73.5	2163.0	6.17	10.9
CGR 002	mining area	0.00	**8046.3**	0.0	12.2	28.2	0.0	4.48	14.7
CGR 003	mining area	**116.60**	**2718.6**	**51.3**	0.0	29.1	4010.3	7.83	2.8
CGR 005	mining area	0.00	**4994.4**	**36.0**	**121.5**	29.3	5624.3	5.05	4.3
CGR 006	mining area	0.00	**31491.1**	**401.5**	67.7	33.0	7985.6	6.54	5
SKY 001	lim. pav.	**349.00**	**3901.5**	**62.2**	0.0	61.3	3920.6	5.89	8
SKY 002	lim. pav.	0.00	**3084.2**	0.0	0.0	70.4	2514.0	5.44	8.2
SKY 003	lim. pav.	0.00	**13970.8**	0.0	**103.5**	**123.6**	426.3	5.92	5.9
SKY 004	lim. pav.	0.00	**3137.0**	0.0	**188.9**	**93.5**	3877.7	5.93	5.4
GRW 002	woodland	**6.50**	84.3	0.0	0.0	**83.3**	2851.6	7.55	7.9
GRW 003	woodland	0.00	**12810.3**	**34.8**	**94.3**	**79.3**	2532.3	5.35	4.3
OGB 001	mining area	0.00	**2797.4**	**38.0**	0.0	6.1	971.9	5.85	8.7
OGB 002	mining area	0.00	**4126.4**	0.0	**4814.9**	20.2	1428.9	7.31	4.1
TWR 002	mining area	0.00	**2284.0**	0.0	0.0	2.9	568.0	5.22	5.6
GAS 1	lim. pav.	0.00	**11208.1**	0.0	0.0	40.4	516.1	5.2	28.18
GAS 5	lim. pav.	0.00	**350.0**	0.0	0.0	45.1	762.8	4.56	23.42
TCL 5	lim. pav.	0.00	**358.0**	4.6	**78.0**	**186.0**	6975.7	6.89	32.25
TCL 6	lim. pav.	0.00	**13001.8**	**55.2**	**214.9**	**97.2**	1411.9	4.93	18.15
FF 7	lim. pav.	0.00	**4095.1**	0.0	**95.1**	**97.6**	618.3	5.95	13.67
NBC 2	lim. pav.	0.00	**768.0**	0.0	0.0	**83.4**	52.2	5.69	25.98
COP 3	lim. pav.	0.00	0.0	0.0	0.0	0.0	0.2	6.05	19.39
COP 4	lim. pav.	0.00	**3285.2**	0.0	47.2	**86.9**	6979.8	6.23	19.31
HRC 9	lim. pav.	0.00	0.1	0.0	0.0	0.0	0.3	5.74	32.04
HRC 11	lim. pav.	0.00	**666.7**	0.0	63.5	11.7	498.9	4.61	32.21
ASC 3	lim. pav.	0.00	**5561.2**	0.0	**183.1**	**115.3**	2780.6	7.26	37.15
background concentration		0,5	25	15	30	30			
pol. lim. value in Hungary		1	100	30	75	75			
pol. lim. value in England		1	50		50	50			

The organic matter content of the soils on Aggtelek Karst is higher than in Mecsek. This is because of the different soil type: the rendzinas have usually much more higher organic matter content than the brown forest soils have. The English samples can be divided into two parts according to the different methods. The samples which organic matter content were determined by titration have lower contents than the soils of spectrophotometer's method.

CONTENT OF HEAVY METALS IN THE DIFFERENT SAMPLES

Cadmium: There are only 3 samples in Mecsek and 5 samples on Aggtelek Karst where the Cd content is much higher than the permitted value. There is no Cd in most cases of the English soil samples but there are 7 samples where the Cd content is much higher than the pollution limiting value. Only one of these extremely high Cd polluted samples are on mining areas, 3 of them are in dolinas.

Lead: The Pb content of soils is lower in every sample in Hungary than the pollution limiting value. The data are a bit lower in Mecsek than on the Aggtelek Karst. According to the limiting value of England, most samples of Aggtelek Karst must be qualifed as polluted. There are only 3 of the 41 English samples where the soils have not higher Pb content than the permitted value. The Pb contents are very high, not only on mining areas but in other areas as well. The data are 20-200 times higher than the permitted value.

Nickel: Almost all of the samples on Aggtelek Karst have higher Ni content than the pollution limiting value (average 50-70 ppm). The situation is better in Mecsek, where only 7 of the 23 samples have higher Ni content than 40 ppm. If we investigate the limiting value of England (30 ppm) then the Mecsek samples must be considered as polluted. The Ni content of the soil samples of England was not measured.

Cobalt: In respect of Co the condition of soils is good in the investigated Hungarian areas. There is no soil with Co content higher than the permitted level. 12 of the English samples are polluted and some of these samples have very high Co content. In the other English samples the method which was used was not able to show any Co.

Copper: Every soil sample in the Aggtelek Karst has a high Cu content, above 200 ppm. The values are about 3 times higher than the pollution limiting value of Cu. A smaller part of the English soils have higher Cu contents than the permitted level and the data are about as high as on the Aggtelek Karst. There is one very polluted sample in an English mining area. The situation is the best in Mecsek, where we did not find any samples with Cu content higher than the limit.

Chromium: Just as in the case of the other heavy metals, the condition of soils is the best in Mecsek Mountains as regards Cr. All samples on Aggtelek Karst have a higher Cr content than the pollution limiting value of England. But if we investigate the problem in respect of the Hungarian limit then only 1 sample exceeds the limit. The English samples have the highest Cr contents, a lot of them are above the limiting value.

Manganese: The soils on Aggtelek Karst have the lowest Mn content of the 3 areas. The samples of Mecsek have slightly higher values but we found the highest Mn content in the English samples. The Hungarian soils reflect the average Mn content of limestone (700 ppm).

TENDENCIES OF HEAVY METAL CONTAMINATION

The soil samples in Mecsek Mountains are in the best condition in view of heavy metals. There are problems only in the case of Ni (almost in all soil samples if we consider the English pollution limiting value), and the Cd content of some soils is a little higher than permitted.

On the other Hungarian area the condition of the soils is worse. In respect of Pb and Co we did not find problems. But the Ni and Cu contents are higher than the Hungarian pollution limiting values. If we consider the limiting values of England than the Cr and Pb contents of soils are higher than the permitted values. In 5 samples the Cd content causes problems as well.

Cu becomes more mobile when pH < 4.5 so at the present time this heavy metal is not so mobile in the soils of Aggtelek Karst because the pH of soils > 4.5 in most cases. The Ni - which tends to go to solution pH under 5.5 - can cause greater problems than Cu while there are a lot of acid soils (pH < 5.5) both in Mecsek and on Aggtelek Karst. In these soils the mobility of Ni increases. The mobility of Cd increases when pH < 6.0-6.5 so we have to pay attention to the polluted soils especially on Aggtelek Karst. The mobility of Pb is not so great when pH > 4.0 so at this moment the condition of soils is good to retain the lead.

The English soil samples have higher heavy metal contents. There are many soils in which the Cd, Co and Cu contents are not traceable but in the other samples these heavy metals present in a very high quantity. In the case of Pb and Cd the overstep of pollution limiting values are extraordinarily high. This can cause very serious problems while the low organic matter content and acid reaction of soils cannot retain such quantities of heavy metals even if the mobility of metals is not so great in normal cases in such soil reactions. The higher heavy metal contents in England are partly caused by the more intensive anthropogenic effects: the mining of lead and other, usually non-ferrous metals have polluted the soils with heavy metals. On the other hand this pollution probably comes from areas of volcanic rocks in North-West England. These metals were transported within glacial debris on to the limestone areas. There was no mining activity in the investigated Hungarian areas. Here the soils are polluted mainly by deposition.

Table 5 Correlation coefficients in the different study areas

	Correlation coefficient						
	Cd	***Pb***	***Co***	***Cu***	***Cr***	***Mn***	***Ni***
Mecsek pH	0.5593	0.4739	0.1080	**0.6976**	**0.6652**	**0.6388**	**0.6919**
Mecsek org. mat.	**0.6062**	**0.6689**	0.2373	0.5338	0.4517	0.5500	0.4768
Aggtelek pH	0.1159	-0.2980	-0.1915	-0.2680	-0.1414	0.5131	-0.1756
Aggtelek org. mat.	0.3753	0.2999	-0.2237	0.4843	0.1066	0.1819	0.1228
England pH	-0.2423	-0.1322	0.0932	0.2886	0.3792	0.4500	
England org. mat.	-0.2299	-0.3681	-0.1685	-0.1000	0.1558	-0.0989	

For the investigation of the connection between pH and heavy metal content and the connection between organic matter content and heavy metal content we determined the correlation coefficients of these data (*Table 5*). In the soils of Aggtelek Karst and England we cannot find any connection, the coefficient values are low. But generally we can confirm in the case of soils in Mecsek that the higher the organic matter content the higher the heavy metal content. This is true for the pH as well: the lower the pH the lower the heavy metal content. For Cu, Cr, Mn and Ni the connection is closer to pH than organic matter content (*Fig. 6*). For Cd and Pb the organic matter content has stronger effect (*Fig. 7*).

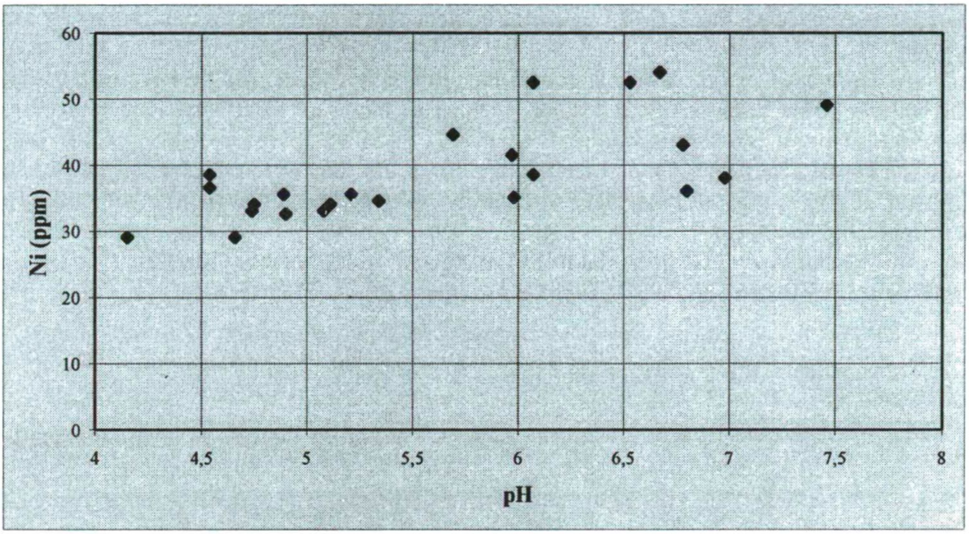

Fig. 6 Connection between Ni content and pH, Mecsek

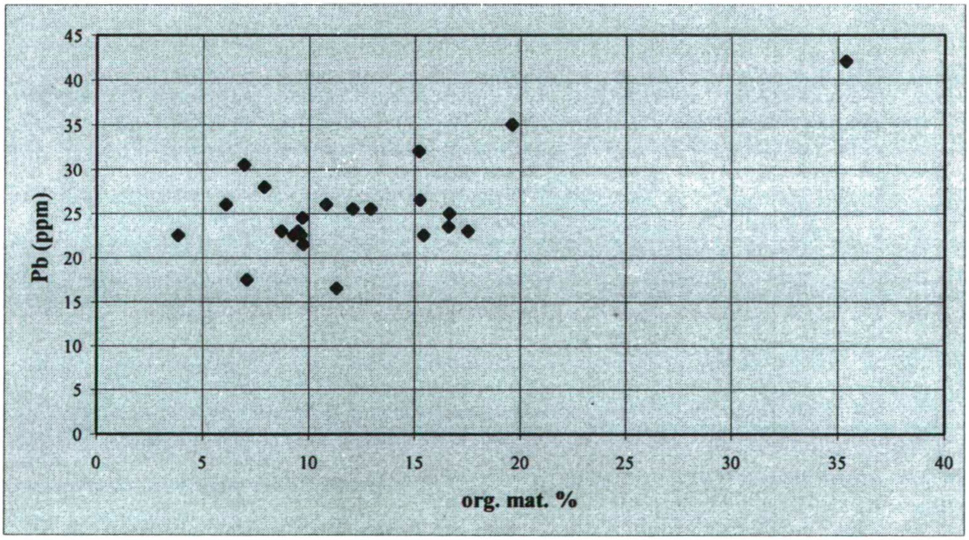

Fig. 7 Connection between Pb and organic matter content, Mecsek

CONCLUSION

At lower pH heavy metals leach from the upper soil layer into the deeper soil layers so the quantity of them is lower in the upper soil layer. The soils with higher organic matter content and higher pH can bind and hold back more+ heavy metals. The greatest problems are in the soils where the high heavy metal content meets low organic matter content and low pH.

The heavy metal contamination in Hungary is not too high. We have to conserve this soil condition because of the further leaching of metal ions will cause problems with the water quality in the karst system.

We detected higher metal contamination on the limestone pavements in Northern England. It means that in these areas the quality of karstwater must be affected and need protection.

Our data were the first data from the Hungarian territories. These data furnish the basis for further investigation of heavy metal contamination of karstic areas.

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CONDITIONS OF ETHNIC MINORITIES IN THE SOUTH PLAIN REGION

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Összefoglalás - A Dél-Alföldön csak a német, horvát, szerb, szlovák és román etnikumok töredéke maradt meg, s arányuk a népesség 1,6 %-ára csökkent. Szegeden viszont különböző etnikumú személyek telepedtek le, egymásra találtak, új etnikai közösségekké formálódtak, s szlovák, szerb, lengyel, román, orosz, német, cigány, vietnami, görög, ukrán, arab, örmény és latin (spanyol) egyesületeket alapítottak. *Exlex* kisebbségek az orosz, a vietnami, az arab és a latin, amelyeknek kisebbségi jogai nincsenek, s egyesületeik csak magyar egyesületként működhetnek. A magyar, cigány és beás anyanyelvű közösségekből álló cigány etnikum a legnagyobb létszámú. A cigány gyermekek nem kapják meg a szükséges segítséget az iskola előkészítéshez és az iskolakezdéshez, ezért tanulásra és önmaguk eltartására egyaránt képtelen évfolyamaik kerülnek ki az iskolából.

Summary - In the South Plain only a fraction of the German, the Croatian, the Serbian, the Slovakian and the Rumanian ethnical groups abode, and their ratio decreased to 1.6% of the population. However, in Szeged persons of different ethnical units settled down, discovered each other, new ethnical communities were formed, and Slovakian, Serbian, Polish, Rumanian, Russian, German, Gypsy, Vietnamese, Greek, Ukrainian, Arabian, Armenian and Latin (Spanish) associations were established. The Russian, the Vietnamese, the Arabian and the Latin are *exlex* minorities who have no minority rights. Their unions can work only as Hungarian ones. The Gypsy ethnical group, which consists of minorities belonging to Hungarian, Romany and Boyash mother tongue, is the greatest in numbers. Gypsy children do not receive any help for preparation before going to school, therefore such Gypsy classes pass out from school that are incapable of learning and keeping themselves.

Key words: South Plain Region, ethnic assimilation, ethnic dissimilation, new ethnic communities, *exlex* minorities, Gypsies.

The South Plain Region is the Southeast part of Hungary, and territories of three counties – Bács-Kiskun, Csongrád and Békés counties – are involved in it. These present counties were established by the administrative reform in 1950 (*Fig. 1*). The territory of the South Plain Region is 18314 square kilometre; in 1998, the population was 1357000 people. The Peace Treaty of Trianon delimited the southern and eastern frontiers of the region as national boundaries in 1920, while the western and northern frontiers were determined as county boundaries in 1950. The law that the total territory of Hungary should be divided into seven planning-statistical regions provides it the three counties together are called South Plain for a long time by Social Geography, but from 1996 on, according to the requirements of European Union[1]. The South Plain Region is one of these regions, and its ethnic conditions are remarkable, independently of association with European Union. (*Rátkai and Sümeghy,* 2000).

Around 5000 BC, new population settled, coming from the Balkan Peninsula to the Carpathian Basin. These neolithic communities were named after the areas of their most

[1] The Act XXI of 1996 on Regional Development and Regional Planning; and the Act XCII of 1999 amending the Act XXI of 1996 on Regional Development and Regional Planning.

significant excavation sites (namely the Körös-culture, Tisza-culture etc.). Later, mainly Iranian, Indoeuropean, Turkic and Mongolian groups (Scythians, Jazygians, Huns, Avars) arrived. In the 9th century (AD), Avars and Slavic population – under Bolgar-Turkic rule – lived in the region, while Hungarians appeared with the conquest, around 895.

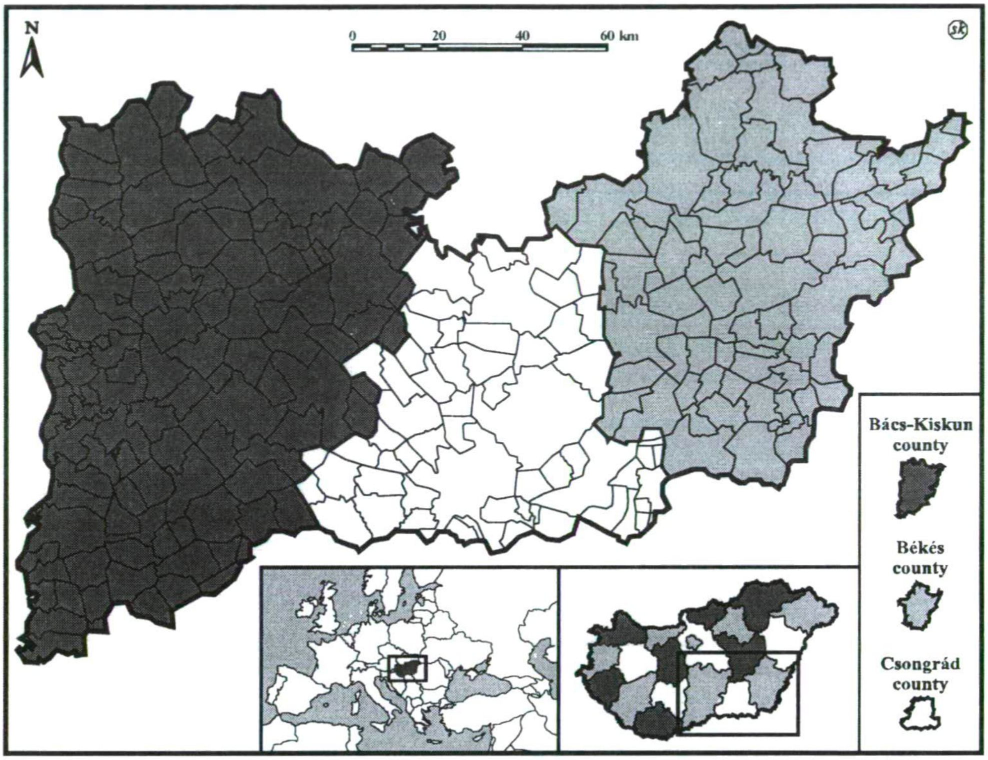

Fig. 1 The South Plain Region

However, some smaller or larger groups of the previously settled population always stayed and were assimilated to the new regime. Similarly, different ethnic groups became parts of the prevailing Hungarian population from the 10th century onwards, among other, western and eastern "newcomers" and the Cumans, who settled in the 13th century, and later assimilated.

Caused by the Turkish occupation and the frequent wars of the 16th-17th centuries, the area mainly depopulated. In the 18th century, ethnic groups with different language and cultural background started to populate this southern region, and created the mosaic picture of the area. The majority of Hungarian population in these places was originated from Baranya, which is west of the Danube, and from the territories lying to the north of the region. The Cumanian and Jazygian, who became considerably Magyarized before, and Gypsies speaking colompar-gurvari dialect occupied the region between the Danube and the River Tisza. Settlements of the southern Slavic ethnical groups, namely of Serbian, Croatian, Catholic Serbian, Dalmatian and Bosnian ones were situated on the south-eastern part of the area. The German were living mostly along the Danube, in Bácska, in some places in Békés county and in Szeged, while the Jews, together with a part of the German in towns (Baja, Kecskemét, Szeged). The largest contiguous area of the Slovak population could be found in Békés county, but some Slovak settlements existed towards the west, in the area of the present Csongrád and Bács-Kiskun counties as well. The Rumanian was living only on the eastern edge of the region. Others besides them, namely the Ruthenian, the Armenian, the Czech, the French, and also other ethnical units, settled in from South Bácska, Transylvania and Banat, too.

CENTURIES OF LANGUAGE-ETHNICAL ASSIMILATION

Until the 18th century, the dividing line existed between different religions and classes of society, but afterwards both nationalism of different ethnical groups and Magyarizing aspirations of Hungarian state step by step gained ground.

After a few generations, families belonging to different nationalities adopted Hungarian ways. In places, inhabited mainly by the Hungarian, first of all in towns, and primarily in Szeged, they got mixed up with Hungarian population, that is assimilated themselves. The assimilation did not always take place as a 'voluntary' or a 'spontaneous' process, but it often was a result of increasing social pressure.

Szeged headed deliberate Magyarization of the region. Here, already in 1775 the independent schools of German and Dalmatian language of teaching were abolished; in 1837, the German singing and sermon were abrogated (*Gergely,* 1985). By 1840, in they made German troupe bankrupt and so expelled it (*Reizner,* 1899). In 1844, in the synagogue Lipót Löw was the first to preach a sermon in Hungarian in our country. Magyarization of the Jews and the German is also mentioned as an example of 'voluntary' assimilation. Behind the spontaneity and deliberateness there were flaring nationalism and such a social atmosphere that did not tolerate strangers.

Became keen on the first successes of Magyarization in Szeged, in 1904, DMKE (South-Hungarian Hungarian Educational Society) was established for the assimilation of non-Hungarian population in the whole Southland (area of mixed population towards the south-east of Szeged).

In 1895, János Reizner, the prominent historian of the city, with exaggeration, wrote the following lines: 'In Szeged, the newcomers were full of enthusiasm thanks to Hungarian genius. They inherited characteristics of the language and traditions, ways of the life, spirit, thinking, emotion and morals in all, without possibilities to maintain original characteristics or translate their attitudes into original inhabitants' life.' The Hungarian genius, of course, would not have been enough to Magyars them (Magyarization). The whole institution system of the state followed Magyarization more and more intensively, and frequently made decisions irrespective of laws. Finally, Reizner himself was forced to admit that it were 'the national spirit of the government and national action of the Church', but not 'the genius' that induced 'citizens of Szeged to became totally Hungarian in their heart, emotion and language.' (*Reizner,* 1895)

Around the turn of the century the assimilatory processes accelerated. 'This fact is a great honour and prominent national merit of Hungarian population in Szeged' – János Kovács, the outstanding ethnographer of the city thought about the course of events (*Kovács,* 1901). It meant that in addition to state and church institution system, the nationalistic general mentality, the increasing intolerance of population towards the non-Hungarian people played an important role in Magyarization.

Both the voluntary and the forced Magyarization took place most rapidly in the largest city of the region, while this process proved to be slowest among the non-Hungarian ethnical groups living in blocks in rural areas. Magyarization of the region accelerated only in the 20th century. After the first world war lots of Hungarian people, moreover the German, escaped from south and east to this region and under the pressure of nationalistic propaganda lots of Rumanian and Serbian people emigrated to the neighbours countries. The peace treaty separately stipulated the option of new subject in case of the Serbians (*Oltvai,* 1991). In Hungary, nationalism and anti-Semitism became more and more pronounced, and led to confiscation of property of Jew descent people; and later on, in 1944 gave rise to their removal by force, to Holocaust. From 1946 to 1948, the majority of the German was exiled to Germany, while the great masses of the Slovakian, in accordance with 'a population exchange', was expatriated to Czechoslovakia. The discrimination of the Serbian and the Croatian became general from 1948 to 1953, during deterioration of our relation to Yugoslavia. Under the influence of all these events, the abandonment of the minority languages accelerated, and the majority of people chose the 'voluntary' assimilation, the assimilation into Hungarians. In 1960, liquidation of the latest, remained educational institutions of the minorities can be considered as the decisive step promoting intentional ethnical homogeneity.

Between 1960 and 1990 the Hungarian dictatorial political system gradually slackened. Undesirable, democratic elements appeared, and became very numerous in it. In the middle of the 1980's, liberalism in political and cultural life gained ground, became uncontrollable; and in 1989, a new, democratic system has been established. The decades of the slackening were favourable for the minorities. Minority politics of the state progressively changed to their advantage.

As a consequence of political change of regime at the beginning of the 1990's, the main characteristics of the new minority politics came into view. The lack of the conception of the previous years was followed by an inconsistent, selective minority politics in the future, too. This trend framed a policy that had different relations to the three groups of minorities living in Hungary:

1. non-Gypsy and non-Hungarian (NN) *de jure* minorities, and
2. the NN *exlex* minorities existing 'only' de facto, and finally
3. the Gypsies existing *de jure*, too.

THE NON-HUNGARIAN AND NON-GYPSY (NN) POPULATION

Population of the South Plain was decreasing from 1960, and its rate in population of the whole country was diminishing, too. Simultaneously, the number and rate of the NN minorities also diminished. Both the native language and nationality were taken into consideration on the occasion of population censuses.

Between figures concerning to mother tongue and nationality-particulars we can notice dissension, difference, frequency of which is proportional to maladjustment that followed assimilation (*Rátkai and Sümeghy,* 2000). This so-called identity-discrepancy can be marked equally in the case of the Rumanian, the Slovakian, the German, the Croatian, and the Serbian (*Fig. 2*). This difference is of a declining tendency, and presumably can be explained with the simultaneous influence of then already existing democratisation-process and the strengthening national sentiment. On the occasion of examining the NN population we always take into consideration the native tongue particulars relating to the level of settlement.

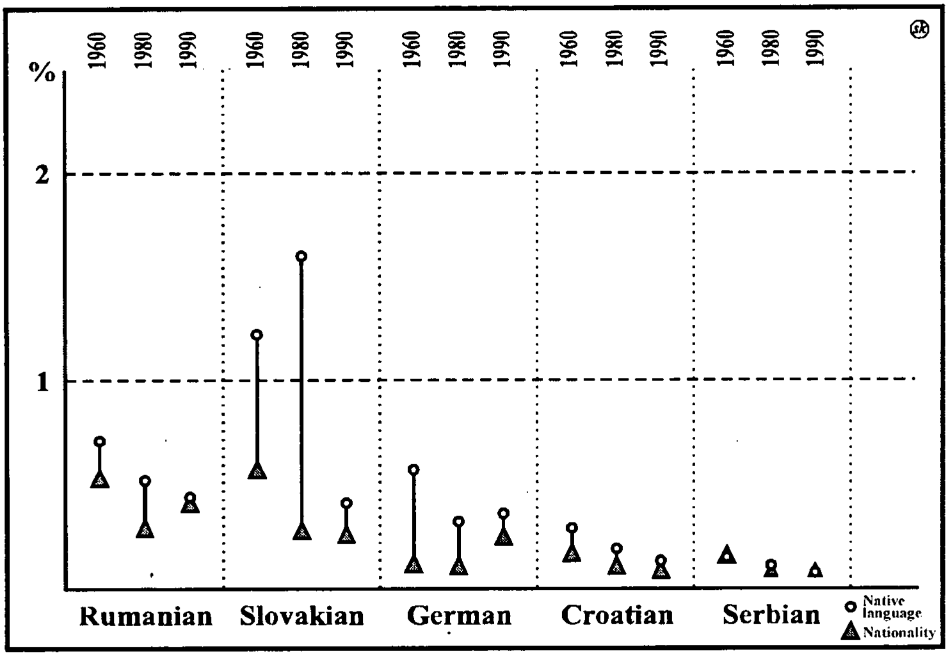

Fig. 2 The different between confessed native language and nationality of five minorities in the South Plain, in percent of the population

The NN-population of South-Plain Region diminished at a quicker pace than its whole population of South-Plain Region diminished from 3% to 1.6% (*Table 1*). Diminution took place in all three of the counties (*Fig. 3*).

Table 1 The total population and the NN-population of the South Plain

Year of census	*Population*	*H%*	*NN*	*NN/SP%*
1960	1488596	14.94	45903	3.08
1970	1472046	14.26	33981	2.31
1980	1462113	13.65	26607	1.82
1990	1395477	13.45	22532	1.61

H% = rate of population in population of Hungary
NN = non-Hungarian and non-Romany native language speaker population
NN/SP% = rate of NN-population in total population of South Plain

It is obvious that decrease of NN-population is of declining tendency, but there is no sign of the stopping of the decrease. In this respect, it is unlikely that we should observe new guideline after the population census due in 2001. In the 1980's, despite of decrease of NN-population, the number of settlements inhabited also by NN-population increased.

In 1980, persons of NN mother tongue lived in 206 settlements, from the total number of 249, while in 1990 - they lived in 226 settlements. If we observe only the most important settlements, that is ones in which at least 20 persons of NN mother tongue live, we can notice increase, too: the number of these settlements increased from 71 to 85. While in 1980, the 98% of the NN-population lived in these 71 settlements, in 1990 a somewhat smaller part of the population, 96% of that lived in far too many – 85 – settlements. Expansion, of course, indicates different-speed in the instance of each minority.

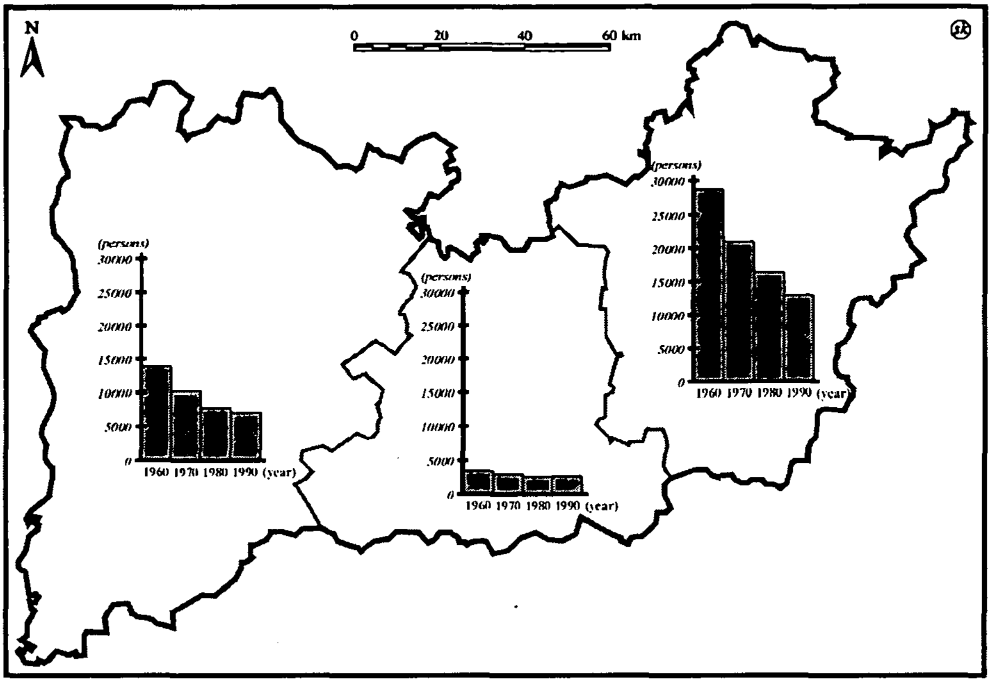

Fig. 3 The NN population in the counties of South Plain in the censuses 1960-1990

The expansion of the Slovakian was of the largest degree: in 1980, persons of Slovakian mother tongue lived in 114 settlements, from the total number of 249, while in 1990 - they lived in 141 settlements. Within 10 years their population decreased from 8825 to 5753, the number of settlements, in which more than 20 Slovakian people live, decreased from 28 to 21. However the rate of the Slovakian living in these settlements diminished from 96% to 91% only. So the Slovakian, who live in bigger blocks, have a fair chance of keeping their identity, but their assimilation to Hungarians in this areas takes place also in quick time.

The Croatian and German live mainly in the south-western parts, while the Serbian in the southern, the Slovakian and the Rumanian live in eastern border territories of the region. (About their settling down in detail: *Rátkai and Sümeghy,* 2000). These border territories economically were underdeveloped before, and in last years their backwardness continued to grow longer. Lack of job opportunities continuously inclines people to migrate from these territories. Improving in effect German, Slovakian and Rumanian cultural opportunities in Baja, Békéscsaba and Gyula could not have stopped this process.

The role of Békéscsaba, with significant help of the state, continued to strengthen in Slovak education and culture; and in 1990, the Slovakian Research Institute was established here. In 1995, in Baja the School Centre of the German Living in Hungary was inaugurated. In 1999, in Gyula in the traffic centre of settlements inhabited by Rumanians, The Rumanian Educational and Cultural Centre was instituted.

THE NN *DE JURE* MINORITIES

At the beginning of the 1990's, the demand on extensive arrangement of minority question strengthened in relation to the distressing juridical and actual status of the Hungarian living in the neighbouring countries. A totally unfounded conception emerged and was effective. This theory emphasised that on mutual terms, by setting to rights of minority position in Hungary the Hungarian politics can reach the same attitude to the Hungarian beyond the national boundary. Though representatives of the state always denied, it was evident that this effort predominated in the minority law of 1993[2]. One of the most obvious manifestations of this effort was the fact that the law acknowledges as Hungarian only those minorities who had lived in Large-Hungary before 1920.

They, except for the Gypsies about whom we will write separately, represent 12 minorities. Five of them (the Croatian, the German, the Rumanian, the Serbian and the Slovakian) live in many settlements of the South Plain, while four of them (the Armenian, the Greek, the Polish and the Ukrainian) live exclusively in Szeged[3] (*Fig. 4*).

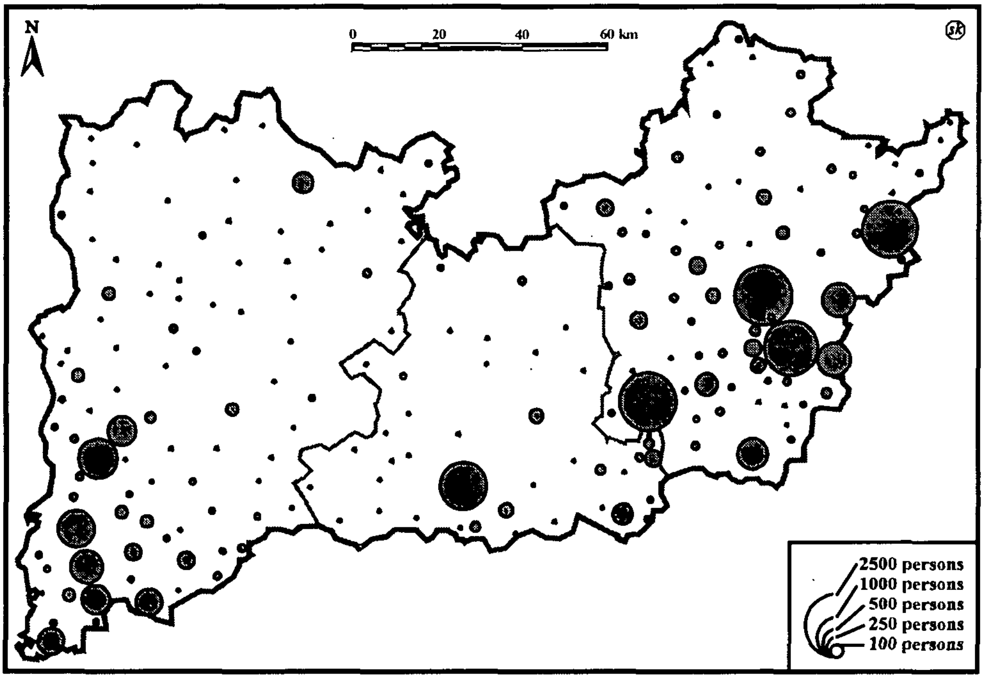

Fig. 4 The population of the NN *de jure* minorities in the settlements of South Plain in the census 1990

The *de jure* minorities that are considered existing ones are termed 'registered minorities' or recently 'indigenous minorities' by the state bureaucracy. These designations prove that the new law acknowledges existence of other minorities, too. The law enabled

[2] The Act LXXVII. of 1993 about the Rights of Nationality- and Ethnical Minorities.

[3] The Bulgarian, the Ruthenian and the Slovenian among the NN *de jure* minorities do not live in the South Plain Region.

the election of so-called minority self-governments. As a result of it, the activity of minorities developed.

In 1994-1995, in 22 settlements 35 minority self-governments were elected (*Fig. 5*); in 1998, in 53 settlements 76 self-governments were formed (*Fig. 6, Tables 2, 3*). In 1998, 26 German, 19 Slovakian, 10 Rumanian, 10 Croatian, 7 Serbian, 1-1 Greek, Polish, Armenian, and Ukrainian self-governments were established, in Szeged 8 of them, in Baja 3 and in further 14 settlements 2-2 were situated (*Rátkai and Sümeghy,* 2000).

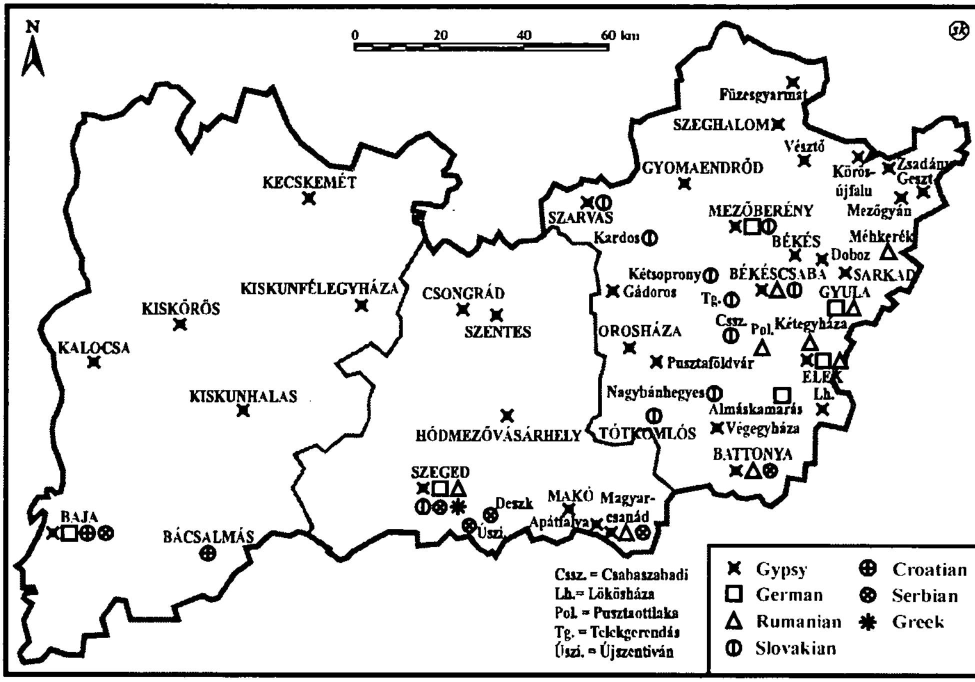

Fig. 5 The minority self-governments in the South Plain, elected in 1994-1995

Table 2 Number of the NN local minority self-governments in the South Plain

Election	*German*	*Slovak*	*Rumanian*	*Serbian*	*Croatian*	*Greek*	*Polish*	*Armenian*	*Ukrainian*	*total*
1994-95	7	10	9	6	2	1	-	-	-	35
1998	26	19	10	7	10	1	1	1	1	76

Table 3 Number of the settlements with NN minority self-governments

Year of the election	*1994-1995*	*1998*
Bács-Kiskun county	2	23
Békés county	16	24
Csongrád county	4	6
South Plain total	22	53

In the election of minority self-governments not only people belonging to the minorities can participate, but also any voter. In this way can it happen that in certain settlements the establishment of minority self-governments was supported by manifold electors than the rate of minority population. People took a stand on minority rights.

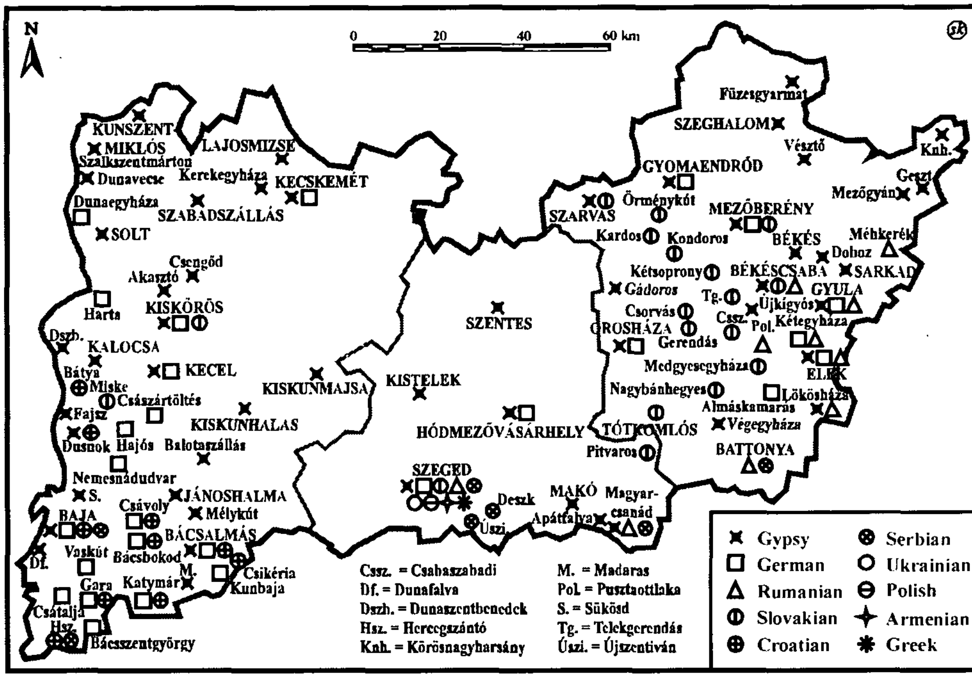

Fig. 6 The minority self-governments in the South Plain, elected in 1998

The state urges the strengthening cultural activity of minorities first of all with the help of minority self-government system. The electoral rules, functional order of self-governments, overshadowing of civil organisations, administration of finances in numerous respects are quite unsuited for serving successfully for maintenance of ethnic-cultural characteristics.

THE ETHNICAL DISSIMILATION

By the 1960's non-Hungarian ethnical units that in the 18th century hadn't been significant factors in Szeged, in the city leading Magyarization, disappeared, assimilated themselves to Hungarian population. In 1960, after the centuries of ethnical homogenisation non-Hungarian population of Szeged was of insignificant number; and in addition to it, these ones did not become ethnical community.

However, in the latest decades of the 20th century in the South Plain certain processes emerged those were in contradiction with the general tendency. The persons and families belonging to different ethnical groups settled in the city independently of each other, from different places and in different times. As a result of immigration, in 1990, 1904 non-Hungarian inhabitants were registered. In the 1990's, their number – in estimation – duplicated. At the same time, we must emphasize an important fact, which is more significant than numerical increase and these are certain signs of ethnical self-organisations, which can be noticed from the 1970's on in this population.

The persons belonging to the same ethnical units gradually got to know each other and became ethnical communities (*Rátkai,* 1998, 1999b,e, 2000). Here, ethnical dissimilation gained ground as against general assimilation in the South Plain. Their societies established in the last quarter of a century endeavour to maintain and secure the ethnic-cultural and language peculiarities of these communities. As a consequence of this process 13 minority organisations were instituted: Slovakian (1975), Serbian (1977), Polish (1978), Rumanian (1982), Russian (1984), German (1987), Gypsy (1989), Vietnamese (1995), Greek (1995), Ukrainian (1996), Arabian (1997), Armenian (1998) and Latin (of Spanish mother tongue, 1999).

The ethnical communities in Szeged are small; their civil organisations have got 20-80 members. These little groups are in contradistinction to communities that are larger than these ones but they are of decreasing population. The inner activity of their organisations is more important than that of state subsidised ones. They are not followers of local traditions but representatives of a new-type culture of ethnical communities living in new city-dispersion. They are not natives of that place, and they did not come to Szeged from one certain settlement, but – even people belonging to the same *de jure* minorities – from different places of the country, moreover, sometimes from abroad. (*Rátkai,* 1996, 1997a,b, 1998, 1999a,b,c,d,e)

THE NN *EXLEX* MINORITIES

From ethnical communities of South Plain, only in Szeged we can meet with the Polish, the Russian, the Vietnamese, the Greek, the Ukrainian, the Arabian, the Armenian and the Latin. The Polish, the Greek and the Armenian were living in Large-Hungary already before the Peace Treaty of Trianon. According to the Minority Law of 1993, the Armenian, the Greek, the Polish and the Ukrainian are of Hungary, on the other hand the Arabian, the Latin (of Spanish mother tongue), the Russian and the Vietnamese communities are not of Hungary, but homeless, or if they are still of Hungary, then they are not minorities. This discrimination used against them is an action followed by considerable consequences. The authorities are willing to enrol their minority societies only on condition that they are not minorities but they are Hungarian cultural societies. According to this idea people belonging to *exlex* minorities are 'cultural Hungarians'. Their judicial status reminds us of the Kurd's life in Turkey who do not exist *de jure* because they are only 'the Turkish of the mountains'.

The *exlex* ethnical communities, whose existence was not recognised, have got very modest and respectable cultural efforts. First of all, they would like to reach that their children should have possibilities to learn writing and reading in their mother tongue, that is they should not remain illiterate. For the sake of the maintenance of their ethnical-cultural characteristics, contrary to *de jure* minorities, they do not receive any state subsidy. For example, programmes of Ukrainian language are state subsidised, while the Russian ones could not obtain any promotion. (It is to be noted that in both cases we observe children of second or third generation whose majority was born as Hungarian subject.)

Division and turning minorities against each other is also an observable state pursuit. It happened in Szeged, too, that the state subsidy was refused from *de jure* minorities because the subsidisation was claimed within the frame of a joint programme with the *exlex* minorities. Factually, in this way, as it were, they punished everybody who would have been inclined to co-operate with *exlex* minorities.

Besides the mentioned ethnical groups, that reached the modern, civil organisation, there are newer ones too; though they have not yet established their minority organisations in the South Plain. From 1989-1990 on groups of the Chinese were settling in larger cities of the region, mostly in Szeged. The majority of their members is not of Hungarian subject yet, and ethnically mixed marriages are more infrequent in their circles than in other ethnical communities. The integration of the lately organised Chinese minority to the society of Hungary presumably will be more complicated than that of the others. The ethnical-cultural differences and differences peculiar to civilised communities between the former ethnical units 'living in Hungary' and the Chinese are not the main causes of the mentioned thought. The state does not make every effort to integrate them, moreover, the official line reacts to their presence in the worst way: it deals with them exclusively as with police causes, and therefore generates conflicts.

Numbers of population, belonging to *exlex* minorities, are one or two thousand. Their population is less by size than people of *de jure* minorities are. If we observe only those people who speak their mother tongue well, than the difference is not so big. In Szeged, the one third of the children of *exlex* ethnical units belongs to the *exlex* minorities. (*Rátkai,* 1999d).

It is a further important factor that the number of the population of *de jure* minorities is decreasing, while the number of *exlex* minorities is increasing. The different manifestations of state administration towards *exlex* minorities are more noteworthy than the mentioned previous element. Certain documents call them 'non-registered minorities', in a concealed way conveying that legally such minorities do not exist (cannot exist). The others consider them simply emigrants, while hiding, that almost every member of certain such communities is of Hungarian subject; in addition to it, the majority of them are belong to the second-third generation, and they are of double culture, they speak Hungarian on mother tongue level.

The politics used against *exlex* minorities is a part of developing antiforeignism which together with anti-gypsy mentality are slowly coming after the anti-Semitism that in the public life is becoming more and more 'outworn'. The positions of *exlex* minorities and the refugees have a lot of common characteristics with the situation of the incomers, which is also very problematical (*Póczik,* 1999). Racism has share in judging of both groups.

In certain respect, the status of *exlex* minorities is worse than that of the refugees'. On the basis of international juridical obligation the state enables the children of the refugees to be educated on their mother tongue. However, if such a refugee of exlex mother language, who obtained state performance, becomes an exciled Hungarian subject of *exlex* mother tongue, and in this case he cannot receive such a subsidy. On the whole, the position of *exlex* minorities is a more serious social-political problem in Hungary than situation of *de jure* NN minorities.

THE GYPSIES

Discrimination towards the Gypsies began in the 18th century, and took shape in a varying way, e.g. marrying of the Gypsies between each other was prohibited, they received new surnames, and their children were taken away from them in order to Magyarize them (*Balogh,* 1997). The Romany, in contradiction to other minorities, remained an excluded part of the society.

Number of inhabitants of the Gypsies is larger than that of other minorities' altogether. The theoretically controversial basic principle of sociological estimations works well in practice, too: Gypsy is a person who is considered as a Gypsy by his environment. The sociological researches are more reliable than census facts.

For the last time such a summing up happened in 1992, and according to its result 36,927 people (*Fig. 7*), that is 2.7% of the population were Gypsies (*Kertesi and Kézdi,* 1998) (*Fig. 8*).

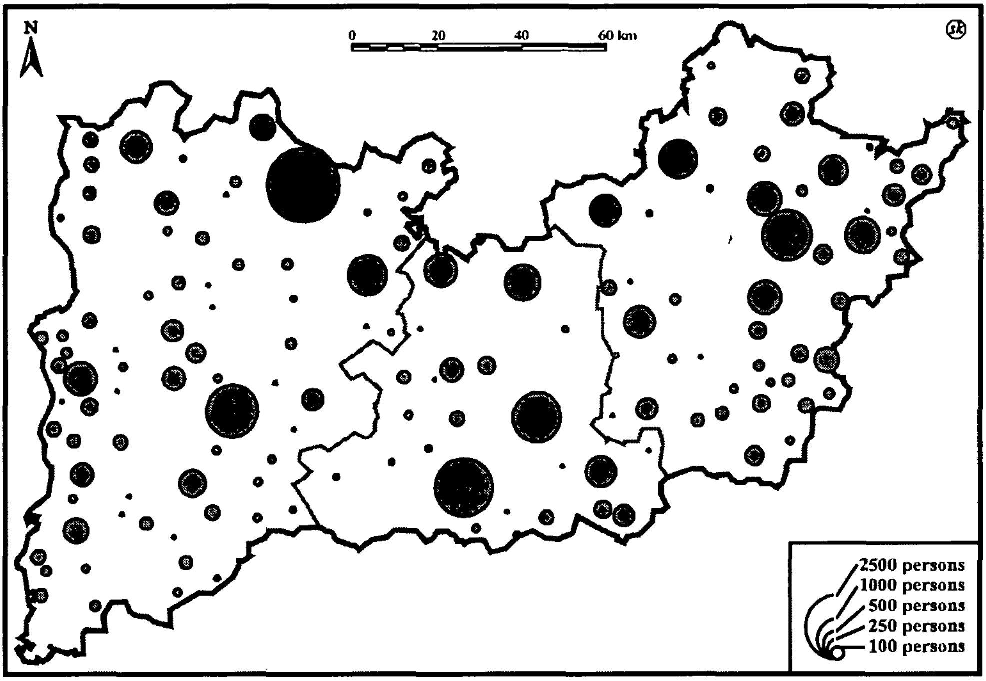

Fig. 7 The Gypsy population in the settlements of South Plain, 1992
(based on *Kertesi and Kézdi,* 1998)

In the largest masses they lived in cities. In 6 cities more than one thousand Gypsies were living: in Kecskemét (3288), in Szeged (2316), in Kiskunhalas (1814), in Hódmezővásárhely (1764), in Békés (1658) and in Kiskunfélegyháza (1105). However, their rate exceeds 10% only in 7 settlements of minor population (Geszt stands pre-eminent among the others with its 29.8%). Although in one third of the 249 settlements on the territories under survey (exactly in 85 ones) did not live inhabitants belonging to Gypsy ethnical minorities at all. It is striking occurrence that the parts, settled by Gypsies in high rate, are situated mainly on the border territories of South Plain Region (both on the western part of Bács-Kiskun lying along the Danube and on the eastern edge of Békés county close to the national boundary). However, in the middle part, in Csongrád county their rate is somewhat smaller (1.9%) than the average.

The Gypsies of the South Plain Region belong to 3 language groups: the Hungarian, the Romanies, and the Boyash (*Erdős,* 1969). The majority of the Gypsies are of Hungarian mother tongue, between them and the Hungarian population there is not a sharp dividing line (*Kemény,* 1999).

Between the Gypsies of Hungarian language and the Hungarians there is an intermediate stratum that becomes wider. The milieu itself is uncertain about judgement of their ethnical status. There are more and more Gypsy-Hungarian marriages, and there are more children who were born in such marriages.

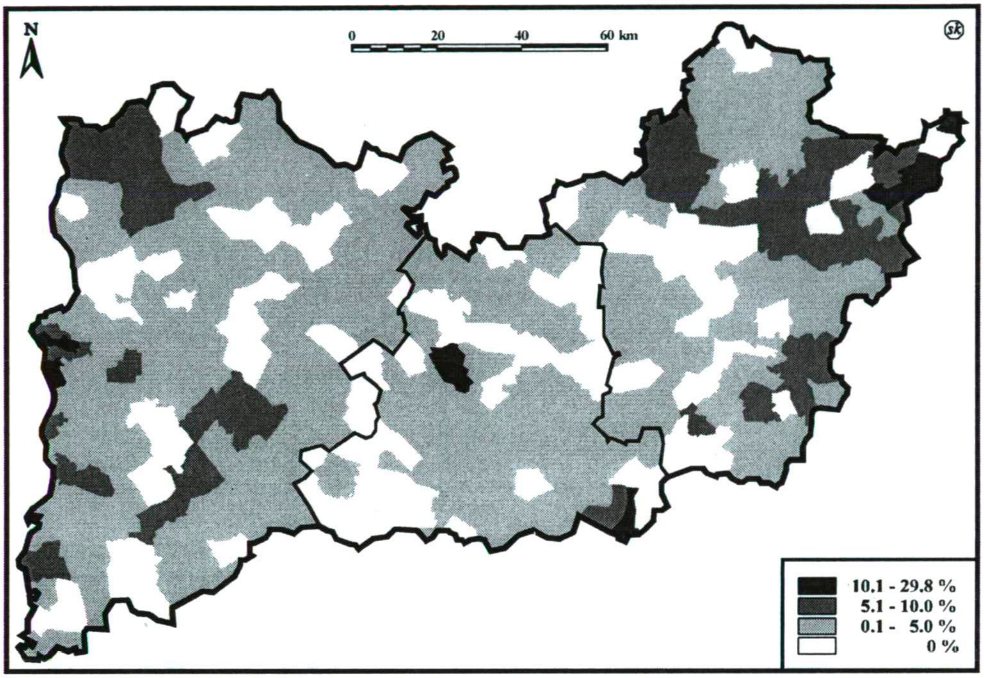

Fig. 8 Proportion of the Gypsy population in the settlements of South Plain, 1992 (based on *Kertesi and Kézdi,* 1998)

The ratio of Romany mother tongue can be estimated only on the basis of details of population census in 1990; their number was the highest in Bács-Kiskun (54%), in Csongrád it was lower (42%), while in Békés it was the lowest (29%). They can be characterised by diglossia, double Romany-Hungarian language. The usage of the two languages are complementary to each other, and in community members' life this double usage plays the same role that the single language does when we speak about unilingulaism. The sphere of applicability of the two languages and their part, filled in communication, basically have nothing in common. The Gypsy mother tongue, learnt in the early childhood, is the intimate, familiar, seldom wider communal, informal usage, while the Hungarian language is more formal, it can be considered as a medium of school-, official, of working place and of communication with members of Hungarian linguistic community. In the region between the Danube and the River Tisza, people of Romany mother tongue speak mostly colompar-gurvari dialect, while in the easterner territories lovari is spoken first of all. Although it's a slow process, but transmittal and usage of the Romany language is being repressed. One of the reasons of it is the low status, the low social prestige of Romany language. Usage of Hungarian language is valued as a symbol of a higher social status. The intermediate stratum between the Gypsies of Romany tongue and those of Hungarian mother language is also wider.

In the South Plain the third group, the minor one is a community whose members are of Boyash mother tongue. They can be characterised by diglossia similar to that of people's belonging to Romany mother tongue. The Boyash language, which is fundamentally a Banate Rumanian dialect from the 19th century, is spoken only in some little settlements. The Gypsies of the South Plain according to their origin, social status, language and traditions, maintenance and abandonment of their identity, their integration level to the society, they live in, is the most proportioned, divided and least unified ethnical group. However, a certain homogenisation took place between them, because they inevitably got into direct touch with other people who spoke different dialects and with people of other tribes. The traditional Gypsy communities gradually disintegrated, the marriage prohibition on marrying people belonging to other tribes was observed more rarely, the tribal endogamy loosened up.

In the 1990's, an opportunity presented itself for Gypsies to establish minority self-governments (*Figs. 5, 6, Table 4*). Presently, in one fifth of the settlements local Gypsy minority self-government works.

Table 4 Number of local gypsy self-goverments

Year of the election	*1994-1995*	*1998*
Bács-Kiskun county	6	26
Békés county	7	7
Csongrád county	21	20
South Plain total	34	53

However, the increasing minority activity of the Gypsies did not result in the improvement of their situation. The education of Gypsies is not organised in territories where they live in large number, and this is the most pressing type of discrimination of Gypsies belonging to Romany and Boyash mother tongue. The majority of Gypsy children do not go to kindergarten, although as a result of their social circumstances, they essentially should grasp the opportunity. After getting school their drawback is on the increase. Improvement can be reached only by changing children's bringing up and education between the ages of 3 and 10. However, their situation did not improve in this respect either.

Unsuccessful learning, repetition of a year's work in school is encountered in the most proportion in their circle as regard school children. After passing out from school they only multiply the number of the unskilled unemployed, and chance of adapting themselves to the society is minimal.

As a consequence of these processes, such Gypsy age groups pass out from beginner's school that are unfit for whatever learning or vocational training, and who are incapable of keeping themselves. These conditions continuously increase social tension and strengthen racism (both in Gypsy and non-Gypsy population).

Taken altogether, the situation of Gypsy population is a much larger and more complicated social problem than that of all other ethnical groups.

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HIERARCHICAL LEVELS AND SETTLEMENT SYSTEMS IN THE HILL REGION FROM NORTH-WESTERN ROMANIA (THE HILLS OF SILVANIA)

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Összefoglalás - Azon tényezők alapján, amelyek egy települést jellemeznek és befolyásolják annak fejlődését (a település típusa, a társadalmi-politikai potenciál, a települések rendszerében elfoglalt hely, a közigazgatási szerep) kiemeltünk 5 hierarchikus szintet a Szilágysági-dombok településein. Kettőt a városi településeknél, hármat a falusi településeknél, ezek voltak: a középnagyságú városok, kisvárosok, községi központok, községek és falvak (ide tartoznak a tanyák is). A településhálózatban létező kapcsolatokból kiindulva és figyelembe véve a központokat, bemutatjuk azokat a területeket, amelyek a nagyobb településrendszerekhez tartoznak. Négy ilyen megyeközpontot határoltunk el, amelyek magukba foglalják a Krasznai-dombságot és a hozzátartozó külső hatásterületet. Zilah településrendszere a legfontosabb ebben a régióban, amelyhez hozzátartozik Szilágy megye négy városa által alkotott alrendszer, valamit a Sarmasági alrendszer. A Nagyváradi rendszer a délnyugati részre, a Margitai és Székelyhídi alrendszerre (Berettyó-Széplak kis részére is) kiterjed. A Szatmár megyei településrendszer magába foglalja Tasnád, Szelestyehuta és Codru-dombság alrendszereit, ez utóbbi közvetlenül kapcsolódik Szatmárhoz. A Nagybányához tartozó alrendszer Codru-hegylábtól Sülelmedig terjed.

Summary - On the basis of the factors which characterize a settlement and influence its evolution (the category of settlement (rural or urban), all types of social-economic potential, the position within the settlement systems, the administrative function) we highlighted five hierarchical levels of settlement within the Hills of Silvania - two belonging to the urban category and three to the rural one: middle- size towns, small towns, intercommunal centres, communal centres and simple rural settlements (which include villages and hamlets). The vertical structure includes the horizontal one (in the field). Going out from the links existing between the components of the settlement network and those of the superior polarizing centres, we identified parts which belong to larger settlement systems, polarized by four country residences which include the hills of Crasna and which reveal the dominant external direction of flows formed here. The settlement system of Zalău is the most important system within this region and it comprises subsystems centred on the four cities of Sălaj Country anmd of Sărmăşag subsystem.The system polarized by Oradea comprises the south-western part, together with the Margita and Săcuieni subsystems (and a small part of Suplacu de Barcău). The settlement system from Satu-Mare County includes Tăşnad, Poiana Codrului and Colinele Codrului subsystems, the latter being directly attracted by Satu-Mare. The subsystem from Piemontul Codrului and Ulmeni is integrated within the settlement system polarized by Baia Mare.

Key words: Romania, Hills of Silvania, settlements, hierarchical levels

THE HILLS OF SILVANIA
FORMING AND GENERAL PHYSICAL GEOGRAPHICAL CHARACTERISTICS

The Hills of Silvania include the hills and depressions, promontories and piedmonts situated between the sunken mountains of the Intracarpathian „yoke" in the east, and the Plains of the Someş and Barcău in the west. Through their position and genesis they belong to the Pericarpathian hills from the west of the Carpathians. The hills of Silvania have close relationships with the Plateaux of the Someş. They were formed through the transformation of the relief, respectively of the underwater edge into a vaste dry land at the and of the Dacian period (*Mac and Idu*, 1992).

The relief of this zone situated at NW of the line of promontories of Meseş-Dumbrava-Ticău, is characterized by a sucession of monocline surfaces, set on several levels.

The Hills of Silvania are of low altitudes (150-400 m) and energy of the relief (60-150 m). In contrast with the general level of the low hills it is detached through rounded forms and dominant landscape of woods on the crystaline promontories: Măgura Şimleului (596 m), Măgura Chilioarei (347 m) and Culmea Codrului (579 m), considered as remains of a mountainous range ruined and sunken. Amongst the crystalline promontories there lie large depressions along the great rivers that cross the contrast with the slopes and interfluves of the general level. Generally, the valleys are unlaterable, having large surfaces with a piedmont character (mostly), and they disappear under the strongly alluviated plains of the great rivers (Barcău, Crasna, Zalău and Sălaj) - which are subsequent here - that gave off the structural fronts of cuestas oriented towards SE.

The relief of the piedmont hills of Silvania have a series of particularities:

- the outstanding assymetry of the valleys, having a monolateral development of the terraces and even of the river meadow;

- the permanent withdrawal of the cuestas either because of their being undermined by the rivers, or – especially - because of the regressive corrosion and generally energetic of the torrents with obsequent character and respectively, because of gravitational processes in the sectors where the cuestas have an active evolution.

The whole region is characterized by an active dynamics of the relief with large processes of erosion brought over by the fragile substratum (marl, sand, clay, pebbles alternating) and on the other hand by recent positive movements (Dealurile Camarului) or the sinking on the rivers Barcău, Crasna and the valley of the Sălaj.

The origin and general traits of the Hills of Silvania bear different nuances that divide the region in a number of units with mountanious structures and they are differentiated according to their dimensions and ecogeographical particularities. Thus, there is a middle line made up of promontories - a horst that appears in the vicinity of the town of Şimleu Silvaniei (Măgura Şimleului) and dissapears close to the locality of Poiana Codrului (Tarniţa 551 m) and includes in the eastern part the Depression of Silvania.

At the level of the hydrographic basins there can be differentiated erosion basins, some of them enlarged and reunited by sadless and gorges/ravines in larger areas that bear the characteristics of depressions: the Depression of Şimleu, the Depression of Zalău and the Sălajului, each of them making up - in fact - an association of hills and erosional enlargements that reflect the structure of the substratum.

In the piedmont hills of Silvania, having a more uniform lithology reflected by the milder morphometrical characteristics of the relief, from the point of view of the needs for s ystematization, there can be found a less diversified and homogenous network of settlements. For this reason the geographical analysis of the whoie region was made in a differentiated way.

The approached region represents the northern compartment of the Western Hills, marking the transition between the Transylvania Depression and the Western Plain of Romania. It extends over 3500 km^2 with a population of 278,000 inhabitants. It includes four counties - Sălaj, Maramureş, Satu Mare, Bihor - 211 rural settlements and five towns (*Fig. 1*).

The urban settlements are located on the outskirts of the Silvania Hills, and only Zalău (72,000 inhabitants), the residence capital of Sălaj County, acquires some significance. The other towns (Marghita, Tăşnad, Jibou and Cehu Silvaniei) have a low demographic potential (between 6200 and 17,000 inhabitants). This accounts for the reduced influence they exert on the neighbouring rural territories. Reversely, main rural areas are polarized by the county capitals situated in the vicinity of the Silvania Hills: Oradea (220,000 inhabitants, the County Bihor), Satu Mare (135,000 inhabitants, the County of Satu Mare, Baia Mare (150,000 inhabitants, the County of Maramureş). Consequently, there is a clear prevalence of the centrifugal forces oriented towards the above - mentioned county capitals (Zalău included), which determined a significant depopulation of the rural space over the last decades.

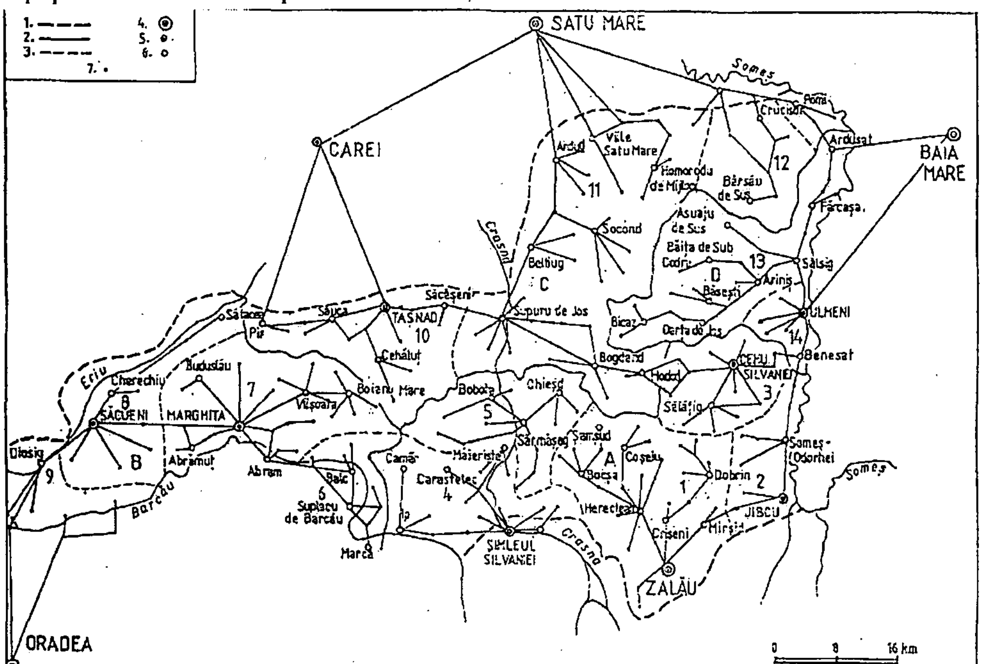

Fig. 1 Silvania hills. Settelment systems. 1. Region limit 2. Settelment systems limits 3. Settelemnt subsystems limits 4. County towns 5. Towns 6. Communal centers 7. Villages A. Zalau settlement system – subsystems: 1. Zalau 2. Jibou 3. Cehu Sivlaniei 4. Simleul Silvaniei 5. Sarmasag. B. Oradea settlement system – subsystems: 6. Suplacu de Barcau 7. Marghita 8. Sacueni 9. Oradea. C. Satu-Mare settlement system – subsystems: 10. Tasnad 11. Satu-Mare 12. Poiana Codrului. D. Baia-Mare settlement system – subsystems: 13. Baia-Mare 14. Ulmeni.

The Hills of Silvania represent a low urbanized area (40% urban population), with rural settlements of variable demographic dimensions (Pădureni 2 inhabitants, Săcuieni 7260 inhabitants). The differentiation process of the settlements, their hierarchization continued alongside the historical development, generally during the 2nd milenium AD.

The scaling of human settlement must necessarily take into consideration various factors, from amongst which the most important are: type of settlement (urban or rural), demographic potential, economic potential, social-cultural facilities and developments related to the location potential, infrastructure network and, mainly to the systems (subsystems) of settlements, and administrative function (*Erdeli*, 1996).

The level reached by a settlement at a certain moment within the frame of habitual hierarchy is expressed primarily through its administrative function. Reversely, the function acts as a stimulus for the development of that settlement. The distribution of administrative functions of different settlement and their level underwent many changes during the last centuries (see the administrative maps from 1920, 1956 and the present one) (*Cucu and Ianoş*, 1988).

Therefore, during the inter- war period (after the administrative reorganization dating back to 1926) Zalău held the highest position amongst the human settlements from the Hills of Silvania, as it was the only town and county capital in Sălaj as well. The next position in the hierarchy was occupied by other regional residence towns, such as: Cehu Silvaniei, Jibou, Marghita, Tăşnad, Săcuieni and Ardud. The third level is occupied by important villages with communal secretary (there were 15 of them: Belţiug, Pir, Sălacea, Camăr etc.) and the fourth by villages with local secretary, which catered for approximately 2 to 4 settlements. The lowest position of this hierarchy was held by simple rural settlements (middle-size or small villages), and hamlets.

The administrative-territorial organization carried out in 1950 determined a certain standardization of the administrative function. Consequently, the county capitals ranked first in the hierarchy - Jibou, Zalău, Cehu Silvaniei, Harghita, Tăşnad, Săcuieni - with Zalău standing out as the only town of the region. It was followed by the local centres and than by the villages and the nearby hamlets.

The present situation highlights a more visible and prominent differentiation of the settlements located in Crasna Hills, especially with regard to the rural category. Considering therefore - mentioned factors - mainly the administrative function, demographic potential - five hierarchical levels of settlements can be profiled, including two urban categories and three types of rural settlement (*Fig. 2*).

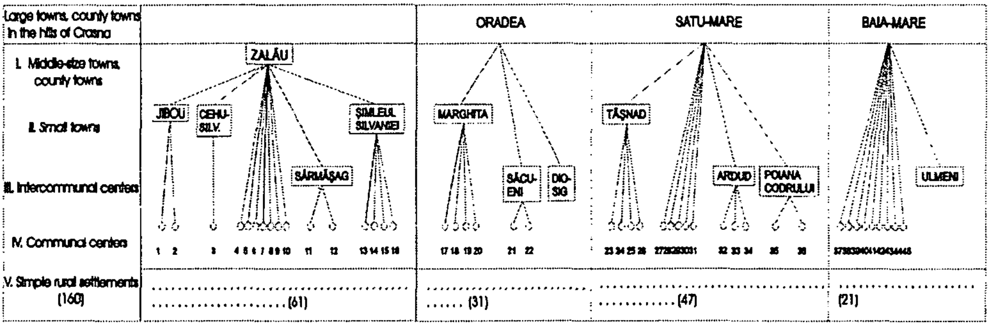

Fig. 2 Hierarchical levels of investigated settlements

These levels should be approached according to a flexible perspective, as each level is characterized by significant variations. Therefore, regarding the demographic potential of Marghita it must be pointed out that it has a double population on average, as compared to the other three small towns. Poiana Codrului and Ulmeni have a population three or four time smaller than the other middle-size or small town centres.

Poiana Codrului is neither a communal centre. The subcategory of small communal centre is also characterized by significant differences - ranging from large villages (Viile Satu-Mare, Sălacea, Camăr, etc.) to small villages (Săuca, Socond, Coşeiu, Dobrin). The lowest level of the settlement hierarchy displays a somewhat greater diversity (Derşida 1910 inhabitants, Ţărmure 5 inhabitants). This calls for a breakdown into two sublevels: villages and hamlets (*Molnar,* 1972).

SYSTEMS OF SETTLEMENTS

The human settlement network of the Silvania Hills shows undeniable relationships between most of its components, extensively facilitated by infrastructure and the communications system. The communications network has a prevailing transversal orientations, connecting the Western Plain to the Transylvanian Depression. More importantly, the railway Jibou - Zalău - Sărmăşag, with its ramifications to Şimleul Silvaniei - Marghita - Săcuieni and to Tăşnad - Carei, and the E 81 highway stand apart. In addition, the roads of the north and south margins (Baia Mare - Satu Mare, Zalău - Şimleul Silvaniei), from the eastern margins (all situated along the Someş River), and the more fragmentary highways located at the contact area of hills and plains must be mentioned. Apart from these, the links reaching out beyond the county limits are rare and are materialized in county roads: Tăşnad - Marghita, Cehu Silvaniei - Supuru de Jos and Sălsig - Cehu Silvaniei.

On the other hand, several significant discontinuities emerge, generated firstly by the administrative borders and secondly by a few strong orographic subunits. Consequently, the main contribution in this respect goes to the county borders, due to the attraction exerted by the four county capitals (three of them situated in the exterior and Zalău at the margins, a phenomenon which also explains the strong manifestation of centrifugal forces within the Silvania Hills. They cause the presence of some highway discontinuities all along the Western limit, north of Barcău, between the south-eastern settlements of Satu-Mare and those from the north-western part of Sălaj county, between Bârsău de Jos and Fărcaşa etc.

Among interior natural units, a more prominent separating role is assigned to the alignment of crystalline hillocks. The largest one is the Codru Hill mainly corresponding to the boundary between the counties of Satu Mare and Maramureş. To the south, the Chilioara and Şimleu hills cause a relative decrease of the influence of Zalău and the gravitation of some settlements of the Sărmăşag - Camăr subarea towards Şimleul Silvaniei.

The presence of mineral resources - mainly lignite - determined attractions over restrained aqreas, the most important being polarized by Sărmăşag, which has also a very strategical position within the local communication system. The oil industry, which does not require a numerous work force, has a poor impact in this respect, although there is a strong tendency of the work force to move from the few towns on the right bank of Barcău River, towards Suplacu de Barcău and Balc. The same type of flow, on a more or less local level, is conditioned by the service supply and the industry of the towns polarized by Săcuieni, Ulmeni and Poiana Codrului.

Given the relationships between settlements with many discontinuities in the territory, given the diverse flow and force directions (mainly acting divergently), it can be asserted that in the Silvania Hills the transition from a network settlement type to a unitary settlement system, characterized by organic structure, complexity, integrity, adaptability

Fig. 3 Silvania hills georgaphical position in the North-West of Romania

has not been completed yet. However, we can highlight the existence of several components of a system and of several subsystems, which can be integrated into larger settlement systems polarized by county capitals and with territories in the Silvania Hills. This calls for the identfication of four general settlement systems that have as centres Zalău, Oradea, Satu Mare and Baia Mare. The polarizing tendency is both administrative and economic, due to the influence of the industry and the service diversity offered (*Fig. 3*).

A. Zalău settlement system encompasses the subsystems centred on the four towns of Sălaj County, and includes the Sărmăşag system. Three of the subsystems extend only partly in the Silvania Hills (*Ianoş,* 1987).

1. ***Zalău subsystem*** includes in its regional territory the settlements of Crişeni, Dobrin, Hereclean, Bocşa, Coşeiu, Şamşud, than the villages Mirşid, Firminiş, Aghireş and Fetidia, which basically represent 28 villages from which 7 are local centres. Their relationships with the county capital are multiple, and are generally decreasing in intensity with the icrease in distance and especially towards the termination of secondary roads. The following deserve particular attention: the supply of part of the necessary work force for Zalău, the commercial links, the food supply of the city. A typical feature of this partial system is the marginal position of the polarizing centre.

2. Similary, the ***Jibou system*** has its centre situated at the margins of the region, but on an important communication axis, a position is mainly reflected in the role that the transport function holds in this small town.

Apart from Jibou, it includes 9 settlements situated west of the Someş River, some of them with a better access to the city and others characterized by a high degree of isolation. The only local center is Someş-Odorhei, with a high communication potential.

3. The ***settlement subsystem of Cehu Silvaniei*** extends over the entire Silvania Hill area (The Hills and the Valley of Sălaj). The closest links with the small polarizing center are held by the villages that belong to the centre, and than by those of the communes Sălăţig and Biuşa from Benesat commune. Westwards, the subsystem reaches out beyond the boundary with Satu Mare and comprises 13 settlements. Three quarters of the villages are middle-size demographic villages while the only communal center - Sălăţig - has little under 500 inhabitants.

4. The ***Şimleul Silvaniei subsystem*** intrudes with its northern and central parts in the Silvania Hill area holding 15 villages, four of which are communal centres. Most of them are oriented toward the Crasna Passages (five villages from Măerişte) and the Barcău Passages (Ip). The others are more isolated within the Camăr Hills (Camăr and Carastelec) or in the vecinity of Măgura Şimleului. Although Camăr and Ip. belong to the large rural

settlement category, the middle-sized settlements prevail, and the small settlements are also existent.

5. The ***Sărmăşag settlement subsystem*** stands out due to its lignite exploitations and due to its role of railway and road junction point, as Sărmăşag represents the only important rural settlement (5 thousand inhabitants) in the Sălaj area. It includes several villages which converge towards Crasna Passage and the villages from the highly isolated Chieşd commune.

During the past decades, when the lignite expolitations enjoyed a greater growth, Sărmăşag attracted a significant amount of work force from the communes oriented towards Şimleul Silvaniei. The role of Sărmăşag within the subsystem was considerably diminished during the last decade as a consequence of the decline of mining activities and further caused the decline of its relationships with more peripheral settlements.

The subsystem with its 15 settlements coincides with an area which does not resent a direct urban influence and consequently, this situation leads to an intense migration process, which also accounts for the high number of small settlements (40%). Three big villages are also part of this subsystem.

B. The **settlement system polarized by Oradea** on the territory of the studied region, comprises its north-eastern part as well. Two subsystems along with a small part of the Suplacu of Barcău subsystem can be identified.

6. The ***Suplacu de Barcău subsystem*** includes 6 villages from the exterior of Barcău River loop (on the right bank). The polarizing phenomenon around Suplacu de Barcău is generated by petrol processing and exploitation activities.

7. The ***Marghita subsystem*** is the most important subsystem from the south-west of the Hills of Silvania. It includes 22 rural settlements, which belong to five communes and to the administrative territory of the town.

More important from the demographic potential point of view are the middle-sized villages (Viişoara and Buduslău, communal centres) located in the northern part. Petreu is the most typical suburban settlement situated in the proximity of Marghita, registered as the only settlement with over 1500 inhabitants. Although the other settlements from Abrămuţ commune stand out for their petrol exploitation, which favoured highly intensive links with Marghita, they record a relatively low number of inhabitants. The agricultural resources of the villages west and north of Marghita are high, and are capable of ensuring the necessary food supply and a part of the work force employed in the town.

However, the rural settlements from east and the north-east of Marghita, grouped within the Abram, Boianu Mare and Viişoara communes, are mainly small and very small. The most frequent cases of settlement regression and of settlements with less than 100 inhabitants are encountered in this region.

8. The ***Săcuieni subsystem*** represents the south-western extremity of the region, in the Ier Passage and its vicinity. The polarizing center, Săcuieni, stands out as the highest demographic potential of this rural region (7260 inhabitants), as a significant services provider (especially commercial and communications) and a manufacturing capacity.

The subsystem mainly gathers middle-size villages from the communes Săcuieni, Cherechiu and Sălacea. Small or very small villages are non-existent. These settlements have a particularly high agricultural potential.

9. The ***Diosig Settlement*** (6200 inhabitants), situated near Săcuieni, on the route to Oradea, cannot be included in the above-mentioned subsystem, because of its strong links with the county capital and because of its high demographic and economic potential (almost touching that one of Săcuieni). Furthermore, it can hardly be considered a center of a different subsystem because of the attraction exerted by Oradea, which affects the cohesion of several settlement subsystems. Thus, the settlements from the extreme southwestern edge of the region belong to the Oradea settlement subsystem.

C. The **settlement system from Satu-Mare County**, centered around its capital, includes even less concentrated parts from the Silvania Hills, according to its strong rural character and, also to its marginal position within the county.

10. The ***Tăşnad subsystem*** has as a polarizing center a small urban settlement (8200 inhabitants) which attracts rural settlements from Tăşnad's Piedmont villages Pir (over 1600 inhabitants) and Sărvăzel from its western extremity develop important links with Carei as well. The other villages are encompassed by the communes Săuca, Cehal and Săcăşeni, by the administrative territory of Tăşnad.

The cohesion of the subsystem is poor; the links with the small polarizing center being accomplished through a relatively slightly modernized infrastructure (except the one from the northern periphery). The village-town links are dominated by food and work force supply, while the reverse link, town to village, is characterized by a strong commercial and transportation character.

11. The ***settlements from the Hillocks of Codru*** and those from the valleys of their south and southwestern parts do not form a system or a subsystem. In general, the mass and energy flows are channeled along transversal axes, concentrating either at the hill peripheral region towards E81 highway (Supur – Beltiug - Ardud) and then towards Satu-Mare, or following separate routes towards the county capital. The depopulation of this territory was very intense between the '60 and '70.

The southern villages are included in the Hodod, Bogdand and Supur communes and the central and northern ones in the Socond, Beltiug, Ardud, Viila Satu-Mare and Homoroade communes. The mentioned area comprises 34 villages, from which 8 are communal centres.

One of the four most extended rural settlements of the region - Ardud (4100 inhabitants) is situated at the periphery of Codrului Hillocks. This can be considered as a commune - polarizing center, but because of its proximity to the county capital, which generates a strong attraction from the hillock region on several axes and, generally, as directly as possible, it cannot form around it a very clear subsystem. There are also many large villages - Viile Satu Mare (2000 inhabitants), Beltiug - and upper intermediate size villages.

12. The ***Poiana Codrului subsystem*** includes the lowest number of settlements (seven). Its individualization depends on the activity of the glass factory from Poiana Codrului, which attracts the work force from the nearby villages and enhances the demographic growth of the town. Similarly, it determined a development of the service industry.

The largest number of villages is gathered in the communes Crucişor and Bârsău. The relatively balanced classification of the villages follows their demographic size. Bârsău de Sus (almost 2000 inhabitants) and Poiana Codrului (1570) are large villages. It is noteworthy, however, that Poiana Codrului is not a communal centre.

D. The **settlements from Codrului Piedmont**, the northern part of the Hills and the Sălaj Passage - situated almost entirely in Maramureş County - are polarized by Baia Mare.

13. The southeastern part of this area is similar to the former subsystem, the ***Ulmeni subsystem.*** The similarities mainly concern the number of settlements (eight), the presence of some industrial objectives in the polarizing center (including the following branches: building materials, textiles - ready made clothes, food industry, wood industry) and

demographic potential - Ulmeni - holds 1670 inhabitants. There are also differences which regard the diversification of services in Ulmeni, and, especially, its high communication potential as compared to Poiana Codrului.

Almost all the polarized villages belong to the Ulmeni commune, to which Benesat (Sălaj County) must be added with a work force mainly oriented towards Baia Mare and Ulmeni. Up to a certain extent the Ariniş village was also (from the inferior passage of Someş River) attracted, but the considerable diminution of the railway transportation on the route Cehu Silvaniei - Ulmeni creates a similar background to the settlements from Codrului Piemont.

The middle-sized villages prevail. The subsystem is connected to Baia Mare by both railway and highway.

14. The ***settlements from Codrului Piemont*** share similarities with those of Codru Hillocks due to their position on the transversal valleys and to the links of their secondary roads to the main road at the base of piedmont. These wind through the inferior flow of Sălaj River and than through that of Someş River which is crosses near Ardusat, linking it to Baia Mare. These settlements do not form a unified system because of the poor links between them. Although the communication system with Baia Mare is complex, it is more intense only with regard to the villages from the Someş Valley and it is diminished towards Culmea Codrului.

The settlements from the interior of the piedmont have a relatively high degree of isolation, being concentrated along the tributaries of Sălaj. Those from the piedmont bottom belong to the communes Ariniş, Sălşig, Fărcaşa, Ardusat. They continue in the villages from Pomi commune, which has a more privileged position to the county capital.

The mentioned area holds 10 communal centres and 17 villages which belong to them. The big settlements (1500-2000 inhabitants) have quite a high weight and except Băiţa de Sub Codru - they align along the Someş.

In conclusion, there is no unitary settlement system within the Hills of Silvania, but only partial or local systems (subsystems). These have no well- defined boundaries, being exposed to changes and depend on the changes and depend on the changes which affect the potential and economic structure of the settlements.

The prevalence of partial systems is revealed by the polarization of 40% of settlements by exterior centre.

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